An Effective Design Course to Inspire Active Learning in Undergraduate Education

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Abstract— The ABET engineering criteria was first formulated and introduced to the American education system in the middle 1990s. The ABET accreditation system defines an engineering graduate according to Blooms Taxonomy. As a part of the continuing curriculum improvement at Bucknell University, a new junior-level design course has been recently introduced into the curriculum. The course title is ECEG 301: Praxis for Engineering Design. The objectives of this course are manifold, but is primarily designed to pave the way to improved student performance in senior design projects, promote team-work and hands-on experiences, and to enhance student completion of ABET outcomes, particularly criteria (c to h). Examples of the course contents include computer aided design (Solidworks®), 3-D printing, design process elements, functional decomposition, fabrication, implementation, and simulation of photovoltaic systems. The course also aims at introducing students to crucial and current societal and environmental issues. In this paper, the results of the multiple projects are discussed. Based on anecdotal data analysis and feedback from students and faculty, the assigned projects have encouraged students' creativity and enhanced their ability to work on multidisciplinary teams. The inclusion of similar courses in undergraduate engineering curriculum would definitely improve students' hands on experiences and prepare them for more complex design challenges.

Keywords—design, creativity, teamwork, projects, modeling, simulation, fabrication, PV systems.

I. INTRODUCTION

As a part of the continuing curriculum development at Bucknell University, the Electrical and Computer Engineering Department (ECE) introduced a new design course into the ECE curriculum in 2014 based on a recommendation by the ECE Design Working Group. The course targeted the junior students and it is name is ECEG 301: Praxis for Engineering Design and it is a project-based learning course (PBL), in which students are introduced into various engineering experiences. Moreover, through this course, students are provided with opportunities to learn through hands-on experiences that, in addition to being creative, challenge them to think critically, communicate effectively, and work in teams to handle problems similar to those in a realistic engineering setting. These experiences would enhance students' completion of ABET outcomes, in particular (ABET criteria l, m, n, and o) [1, 2, 3], and would pave the way to improved student performance in senior design project. More prominently, students would revamp their communication skills (ABET criterion g) through numerous individual, team, and poster presentations. The course objectives and learning outcomes are discussed in section II.

With the new challenges and nowadays competitive market, graduates with B.S. degree in engineering are expected to work on multidisciplinary teams, in which engineers need to do some work on subjects outside their major. For instance, subjects like 3-D printing, printed circuit boards (PCB), use of different simulation packages such as Matlab/Simulink [4], power system computer aided design (PSCAD) [5], hybrid optimization model for renewable energies (HOMER) [6], are currently being widely used by people from mechanical, electrical, computer, and environmental engineering. It has therefore become necessary to equip engineering students with the hands-on and minds-on experiences that are often required by industry and engineering firms. The Inclusion of PBL courses, such as the one proposed in this paper, would tremendously help students touching upon numerous subjects that they may not get the opportunity to know about during their undergraduate degree. The introducing of such courses at the undergraduate level would also have a great impact on the skills that the graduates need for their professional career.

Numerous nonconventional and active learning based methods have been recently presented in the literature. Of these methods, project-based learning methods have proven to be effective meaning to promote undergraduate students' experiences and to equip them with the skills that they need for their professional career [7, 8, 9]. In this context, Zhang et al. [10] presented methods and summarized the experiences gained from teaching a PBL power electronic course at the Technical University of Denmark. In particular, the PBL learning method in [10] targeted the design of switching-mode power supplies. Students designed their projects from the selection of the topology until the realization of the circuit and meeting the design criteria. In [11], a PBL course to teach speed control of induction machines using V/F control is presented. In [11], students gained knowledge, through implementation, on several related topics such as power electronics, control, and electric machinery.

II. Contribution of Course to Meeting the Required Program Outcomes

This new course provides the B.S. engineering students at Bucknell University with a breadth of knowledge in electrical and computer engineering. Though the main objective of the course is to provide students with the necessary hands-on experiences for the senior design, the course also focuses on improving students' communications skills and supports instructional tools for several program outcomes, in particular outcomes (l, m, n, and o), according to the ABET engineering guidelines (*Criterion 3*). The following measurements standards are proposed to relate the learning objectives to the desired ABET program outcomes:

Significant: 1 Moderate: 2 Not significant: 3

(a) An ability to apply knowledge of mathematics, science, and engineering (1).
(b) An ability to design and conduct experiments, and to analyze and interpret data (1).
(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic and environmental constraints (1).
(d) An ability to function on multidisciplinary teams (1).
(e) An ability to identify, formulate, and solve engineering problems (1).

(f) An understanding of professional responsibility (1).
(g) An ability to communicate effectively (1).
(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (1).
(i) A recognition of the need for, and an ability to engage in life-long learning (2).
(j) A knowledge of contemporary issues (2).
(k) An ability to use the techniques, skills, and modern engineering tools necessary for
engineering practice (1).
(l) A knowledge of probability and statistics, including applications appropriate to the program name (3).
(m) A knowledge of advanced mathematics through differential, integral calculus, linear algebra, complex variables, and discrete mathematics (3).
(n) Ability to analyze and design complex electrical and electronic devices, software, and systems containing hardware and software components (1).
(o) Ability to work on multiple tasks (1).

III. Proposed Course Contents

The course begins by introducing students to general design process, which includes setting up of constraints and criteria for typical engineering problems. The course promotes creativity in engineering fields, highlights the benefits of teamwork, and discusses ethical and contemporary issues in nowadays engineering context. In this course, the instructors have assigned five design projects, several readings, reports, and homework assignments. The 16 week plane for the course is presented in Table I. The details of the assigned projects and their description are discussed in the subsequent section.

TABLE I: PROPOSED COURSE CONTENT

Week	Class Lecture / Readings	Class/Laboratory Activity
1	Intro to design process	Tutorial on Solidworks®
2	Intro to design process – Elevator Pitch discussion Reading from Text Book [12]	Tutorial on 3D printing, 3D Printing exercise – Complete Project #1 (Individual)
3	Review of constraints in the design process Reading from Text Book	Begin Project #2 – Individual work
4	Intro to 6-design step process Readings from Text Book	3D CAD project #2 preparation / functions
5	Intro to Presentations. Student presentation on contemporary engineering topic Readings from Text Book	Work - Project #2 / Presentations
6	Design/Model Simulink Design	Commence Work - Project #3 Functional Decomposition
7	Design/Model Simulink Design	Work - Project #3
8	Design/Model Simulink Design	Work - Project #3
9	Design/Model/Device – PV Lamp	Work – Project #4

Week	Class Lecture / Readings	Class/Laboratory Activity
10	Design/Model/Device – PV Lamp	Work - Project #4
11	Design/Model/Device – PV Lamp	Project #3 / Project #4 demos
12	Intro to global and societal problems	Research open ended topics for project #5
13	Design process pedagogy	Present Project #5 Individual Work Form Teams for Final Project #5
14	Design process pedagogy/MS word Project	Work on project #5
15	Design process pedagogy	Work on project #5
16	Final Presentation	Poster Presentation

IV. ASSIGNED PROJECTS

The instructors have assigned five main projects in addition to several readings, reports, and homework assignments. The assigned projects covered several topics in electrical engineering curriculum such as design work using Solidworks®, 3-D printing, design process elements, functional decomposition, implementation, and simulation of photovoltaic systems. In this section, the main projects will be introduced and briefly discussed.

A. Project I

In the first project, students were asked to model and design a pod-port cap for a BNC adapter board for a Digilent Analog Discovery Accessory™. Students were given extensive tutorial on computer aided design, in particular how to create drawings using Solidworks®, and also on how to use the 3-D printing. The following criteria have been used to assess students' outcomes:

Professionalism – timeliness (can't be late to receive full credit) drawing contains all appropriate information [name, course number, lab section, professors, date, etc.] in the title block of the CAD (Solidworks® drawing)

Completeness – Drawing must be accurate and include scale, all key dimensions called out, legible, appropriate size to be reviewed and used, etc.

- Legible (all notes, words, dimensions, etc. are large and easily read.
- Appropriate Scale selected for visibility of all device features.
- Accuracy and Multiple views for ease of understanding complete design.

Functionality – BNC cap must fit and serve purpose as dust cover.

Creativity – BNC cap may include design element(s) that express the creativity of the designer and these can be described on the Solidworks® design drawing and embodied in the cap 3-D printed.

It is imperative that students have designed 15 different pod-port caps and all of them have met the design criteria. Students also presented their design work via oral presentations and submitted 10 page reports that summarized their design work. Further, the ABET criteria c to h are met in this project. Additionally, we have noticed that students' creativity is promoted as some students designed their caps by including other sustainability/environmental friendly constraints such as material type, size, weight, and volume. We are presenting five different designs in Fig. 1. In Fig. 2, different designs are shown to exactly fit the design criteria.

Fig. 1. Five different cap design. *(Top View)*

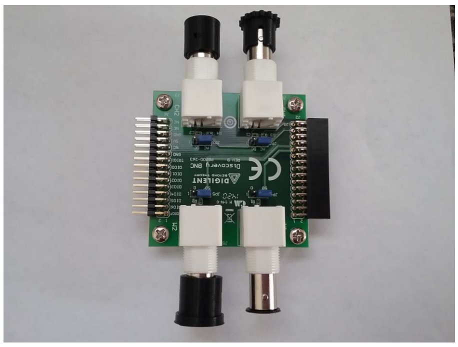

Fig. 2. Design caps exactly fit the BNC ports.

B. *Project II:*

In this project, students were asked to model and design a Pod holder / storage / protection and use platform for a USB Oscilloscope & Logic Analyzer, which is used in conjunction with Digilent Analog Discovery Accessory™. Students developed more than 15 different designs, and have voted for the best design. Two different designs are shown in Fig. 3. In addition, a sample Solidworks® drawing is depicted in Fig. 4. It is worth mentioning here that students were very creative and have taken several other constraints in their design. These other constraints include things like size, color, weight, ventilation, and aesthetical constraints.

C. *Project III:*

In this project, students were asked to model and design a Photovoltaic (PV) system using power electronic interfacing. Students were asked to form teams of three students. Each team was asked to model via Simulink a PV system powering a small inductive load. The crucial goal of this project was to introduce students to design and simulate in Matlab/Simulink environment, with special emphasis on power systems library, power electronics library, and control systems library. Students were given extensive tutorial on power electronics devices, with particular emphasis on modeling aspects of PV panels, DC/DC Buck, DC/DC Boost, DC/DC Buck/Boost, and DC/DC Cuk Converters. Additionally, students were given tutorial on AC/DC half-bridge and full-bridge inverters, low-pass filters, split power supplies, and power distribution. Furthermore, students worked out several examples and exercises on calculating duty cycle, modulation index, and stress-ratio for various power electronics devices. The design criteria were intentionally made similar to those, which are used for realistic PV systems. Therefore, students were asked to keep the ripple in the output voltage and current at minimum. Students developed different designs and disseminated their findings in class through team presentations. For illustration purposes, the entire PV system is depicted in Fig. 5. Sample results of the output voltage and current waveforms are depicted in Fig. 6

Fig. 3. Two different designs of pod holder. *(Project II)*

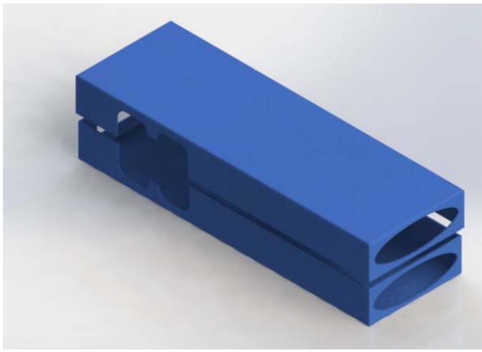

Fig. 4. Two different designs of pod holder. *(Project II)*

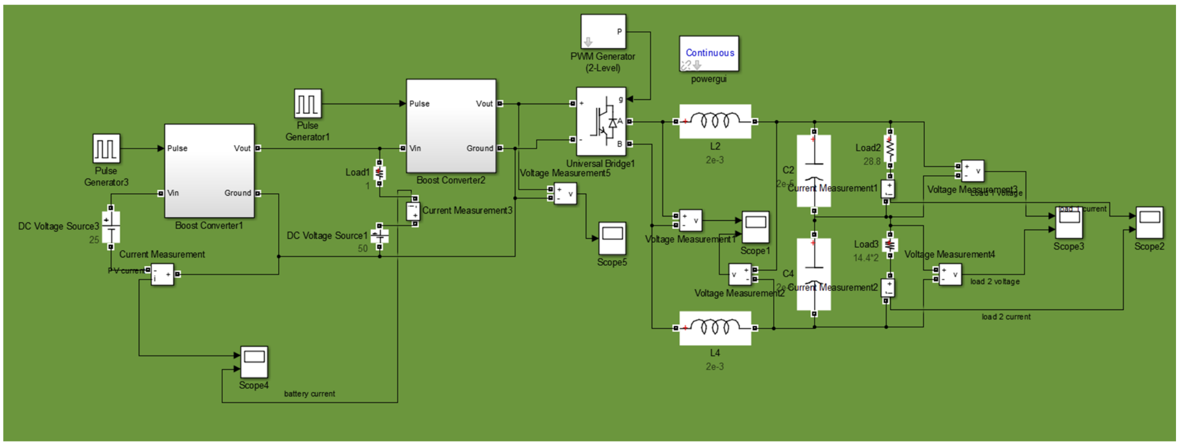

Fig. 5. The entire PV system. *(Project III)*

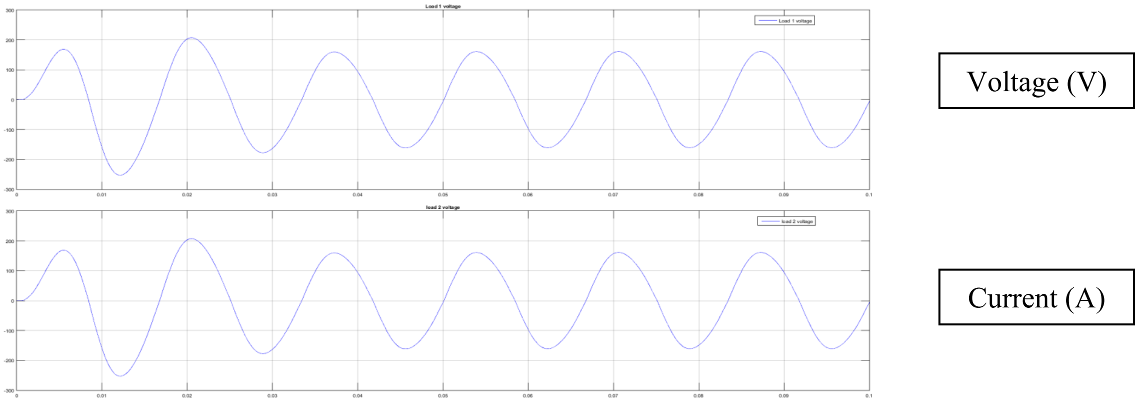

Fig. 6. Output waveforms of voltage and current, respectively. *(Project III)*

D. Project IV:

In Project IV, students were asked to form teams to model, design, and fabricate a Solar PV lantern. All students are assigned more than one duty at a time so several ABET criteria have been fulfilled while students working on this project (ABET criteria (o) for instance). In this project, each team works within collaboration with other functional teams to develop design, model, fabricate and demonstrate a working Solar PV lantern as per below. Additionally, each team is assigned one function of a 5-week project. Also, students are divided in Poster and demonstration session. Students have also given an opportunity for extra credits based on their presentation at the Bucknell's Engineering Expo, which was held on Campus in April 2016.

Light emission and direction Team: *This team focuses on understanding and designing the light emission portion of the PV lamp.*
Energy Storage Team**:** *This team is responsible for the battery type, specifications, overcharging protection, and implementations of the PCB circuit.*
Energy Harvesting Team: *This team is responsible for the energy harvesting part, which includes the selection of the PV panel, its rating, and to calculate the total sunlight that is required to power the panel for the required hours.*
System Integration and User Control Team: *This team is responsible for the fabrication part, including the PCB part.*
Case and integration team: *This team is responsible for the casing and integration part.*

It is imperative that the assigned teams designed and fabricated two different Solar PV lanterns. The results of this project are shown in Fig. 7 through Fig. 12.

E. Project V:

Project V is an Open Ended Human Need Project, which is now being underway. In this project an introduction to global and societal problems (*IEEE Global Humanitarian Engineering Awards, UNEP, NAE Grand Challenges, etc.*) is required. Furthermore, students make proposal and present case for the design they desire to pursue. Each project must have societal, environmental, and economic analysis and/or constraints to be considered. All individuals vote for top projects and are placed on teams to develop solution. Final design process pedagogy presented by instructors. Teams work on projects that have been selected and carry them through the complete 7-step design process from research through reporting. Final project presentations (and research IEEE format report summaries for our BU ECE Design Journal) are given and peer reviewed before class in Final Exam period.

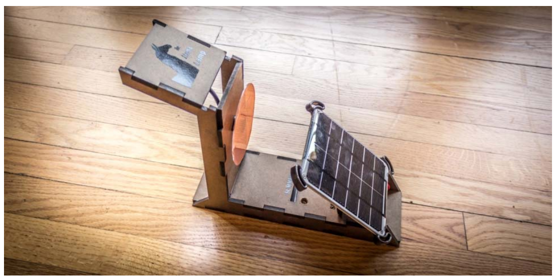

Fig. 7. Solar PV lantern for Team 1. *(Project IV)*

Fig. 8. Solar PV lantern for Team 1. *(Project IV)*

Fig. 9.   Solar PV lantern for Team 2. *(Project IV)*

Fig. 10. Solar PV lantern for Team 2. *(Project IV)*

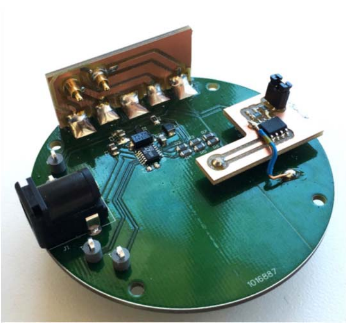

Fig. 11. Inside Solar PV lantern for Team 2. *(Project IV)*

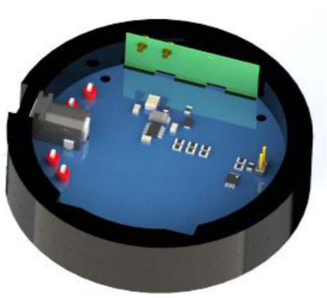

Fig. 12. Inside Solar PV lantern for Team 2. *(Project IV)*

V. Concluding Remarks

This paper summarizes the authors' experiences in teaching a new design course at Bucknell University. The course objectives are manifold; however the course mainly focuses on providing the ECE students at Bucknell University with the hands-on through hands-on experiences that, in addition to being creative, challenge them to think critically, communicate effectively, and work in teams to handle problems similar to those in a realistic engineering setting. These experiences would enhance students' completion of ABET outcomes, in particular (ABET criteria c to h), and would pave the way to improved student performance in senior design project. Through several presentations and feedback from students and faculty, we have noticed that the level of confidence of students have improved, and this has fulfilled the ABET criteria (g). Several other improvements into the course contents are underway and will be reported shortly in due course.

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