Sustainable Change in a First-Year Engineering Program

Jon Sticklen
Eng. Fundamental Dept.
Michigan Tech
Houghton, MI USA
sticklen@mtu.edu

A.J. Hamlin
Eng. Fundamental Dept.
Michigan Tech
Houghton, MI USA
ahamlin@mtu.edu

Amber Kemppainen
Eng. Fundamental Dept.
Michigan Tech
Houghton, MI USA
amber@mtu.edu

Brett Hamlin
Eng. Fundamental Dept.
Michigan Tech
Houghton, MI USA
bhhamlin@mtu.edu

Doug Oppliger
Eng. Fundamental Dept.
Michigan Tech
Houghton, MI USA
oppliger@mtu.edu

Abstract— **This Work in Progress, Research-to-Practice report focuses on an overview of an extensive project to update the First-Year Engineering Program, Michigan Technological University. After three planning years, and multiple pilot course offerings, we rolled out at scale in Fall, 2017. Our core student outcome goals in the revamped first-year program include strengthening the ability for open-ended problem solving, enhanced facility with computational problem solving applied to engineering problems, and increased student growth in traits of self-starting learning and positive attitudes for life-long learning. In this report, we describe both the core components of our revised program and the process we have followed to gain support for our revised first-year program, thus promoting program sustainability. We conclude with a core list of research questions we will pursue beginning in AY 2018-2019.**

Index Terms -- **Curriculum development, engineering education, first-year engineering education, programmatic change, mentoring.**

I. Introduction

This WIP paper describes a program for a systemic update in the first-year engineering program (FYEP) of Michigan Technological University (Michigan Tech). During the last three decades, innovation in engineering education has produced results over a broad range of topics. These include: systems-focused pedagogies (e.g., problem-based learning [1-4], and inverted classrooms [5-8]), learning space developments focusing on student collaboration (e.g, SCALE-UP programs [9-11]), computer technology developments making it possible for each student to utilize a laptop computer in the classroom [12-16], instructional materials developments nearing "adaptive instruction" capabilities [17, 18], and models for effective near-peer mentoring, such as the "Learning Assistant" program at the University of Colorado [19-21] and the "Supplemental Instruction" (SI) program at the University of Missouri Kansas City [22-24]) which are best viewed as force multipliers for faculty efforts. Our change target in the broadest terms is to integrate significant components drawn from the work of decades into one model for first-year engineering education that (a) effectively supports our students to achieve outcomes necessary for the attainment of an engineering B.S. degree and (b) delivering this instructional support in an institutionally sustainable way.

Below, we first describe the institutional and program background, and the reasons our environment was fertile ground for programmatic change. Following that, we list our updated programmatic student outcomes, followed by a description of the six core facets of our model for first-year engineering. Then we discuss briefly the college-level perspective on FYEP as an agent of change in our College of Engineering. Finally, we pose the core research questions we intend to pursue over the coming years.

II. Precursors for Change

Michigan Tech is a small, public university focused largely on STEM-education broadly, and specifically on engineering education. The College of Engineering at Michgian Tech is moderate-to-large in enrollment. Our FYEP at Michigan Tech is also moderate-to-large in enrollment and is a common first-year engineering program: all engineering students are required to take basic engineering courses (6 or 7 semester credits depending on matriculation math skills). Each autumn, FYEP welcomes approximately 1,000 new, first-year students.

Unlike the majority of first-year engineering programs, FYEP is the core mission of a department within our College of Engineering organizational structure: the Engineering Fundamentals Department (EF). This may not seem to be a significant point. But for our ability to gain the acceptance of our engineering colleagues, department-level ownership of FYEP has so far been a strong enabler for programatic revision to FYEP. Other factors that play a role as a precursor for our change program include (a) strong support from dean and provost level, (b) assurances from both dean and provost level that negative feedback from students during our period of transition would not negatively impact instructors in the revised courses, (c) feedback from other engineering departments that prompted some of the bedrock changes we have made, and (d) a largely collegial and supportive faculty team in EF.

III. FYEP Revised Program Goals

The one-line vision for our revised FYEP is to support *Students building their foundation to create the future.* The explicit goal of the revised FYEP is: *To prepare students to succeed in upper level engineering curricula by solving open-ended, multidisciplinary engineering problems in an active, engaging, learning environment, while gaining informed exposure to engineering degree programs and career options*.

The revised set of program outcomes is patterned loosely as a modified subset of ABET™ EAC student outcomes, and is listed below:

a. Apply systematic methods for solving engineering problems,
b. Apply computational tools to solve engineering problems,
c. Demonstrate computational programming competencies,
d. Create models and, as appropriate, perform simulations with them,
e. Analyze and interpret observational or experimental data,

f. Analyze ethical issues in the context of the professional engineer,
g. Demonstrate engineering spatial visualization skills,
h. Utilize design process tools to complete an engineering design project,
i. Communicate information, results, and recommendations in written, verbal, and graphic formats, and
j. Function effectively on a team.

The major updates in the FYEP student outcomes all focus on maintaining the traditional rigorous standards of FYEP while broadening to include or further emphasize computational competencies, competencies in open-ended problem solving, and collaboration and communication skills in a professional team environment.

IV. FYEP Program Components & Initial Results

A. Pedagogy/Delivery

Pedagogy is the driving force for our change program. The other elements are all enabling for the focused and appropriate application of a pedagogy that is active, collaborative, and places the responsibility for learning on each student – with the organization, planning, and execution for the classroom instructional team. The pedagogy is an inverted classroom model, with work in the classroom on projects, problem sets, and topical discussion taking place in the collaborative team. The teams each consist of four students. The students operate in a modified scale-up environment.

Preliminary analysis seems to indicate that most students are *not* familiar with the inverted classroom environment. Our approach was to start the entering students in Fall 2017 with an environment that they had not experienced previously; a moderate percentage of students reacted negatively to the experience. By week 3-4, the situation has largely righted itself, although we believe - again from preliminary analysis - that some students did not engage with the "flipped classroom" fully even by the end of the term. This provides our greatest challenge going forward, but we believe that with intentional conversation about the inverted environment and with appropriate scaffolding, most students will come to relish the responsibility that comes with learning. We intend to provide the scaffolding and the intentionality at the start of Fall 2018 in the next iteration of our revised program.

We also plan to have an on going workshop with the faculty team who are the organizers and implementors collectively for our entire program. For some faculty an inverted classroom was new, and somewhat threatening. We believe that with time and effort, the threatening perception of the inverted model will be minimized.

B. Near-Peer Mentoring Program

The pedagogy is the main driver. Our near-peer mentor program proved to be the glue that enabled and sustained student engagement in the course.

The LEarning with Academic Partners (LEAP) program is a near-peer mentoring program that we developed to support students in our first-year engineering courses. This program is based loosely on SI, but has several distinct differences. In LEAP, one Leader is assigned to 24 students in a scale-up class of up to 120 students. The LEAP Leader monitors and guides their students on in-class activities, grades their students' work with strong faculty supervision, and holds one 50-minute LEAP session each week for their students. The LEAP Leader plans and facilitates an active, peer/collaborative learning session, using SI facilitation techniques and strategies to help students deepen their understanding of the material covered in the previous week. Since there are up to five LEAP leaders in a class, a Head LEAP Leader is designated to help facilitate LEAP session planning and to ensure grading consistency. The Head LEAP Leaders are also assigned to a group of students in the class and are typically returning leaders. As LEAP sessions are scheduled into the normal class meeting, attendance is mandatory and 10% of the course grade is dedicated to LEAP attendance and participation.

The LEAP program was piloted in fall 2016 in three of fifteen sections of ENG1101 - Engineering Problem Solving and Analysis (9 LEAP Leaders) and in spring 2017 in three of fourteen sections of ENG1102 - Engineering Modeling and Design (9 LEAP Leaders) and one section of ENG1101 (3 LEAP Leaders). The LEAP program was incorporated into all sections of all first-year engineering courses beginning in fall 2017. In the fall, there were 44 LEAP Leaders, 8 Head LEAP Leaders, and 2 student supervisors. The student supervisors helped with Leader training, giving feedback on LEAP session plans, observing LEAP sessions, and assisted with hiring. In Spring 2018, we increased the number of students assigned to a LEAP leader from up to 24 students to up to 32 students for one term only. There were 25 Leaders, 9 Head LEAP Leaders, and 2 student supervisors. Going forward, we will retain the LEAP Leader to student ratio at 1:24 based on our experience with 1:32 in the spring semester, 2018.

Student feedback on the LEAP program and LEAP Leaders has been gathered through end-of-semester surveys and is shown in Table 1 on the next page.

The response rates varied by semester due to the way the survey was administered, with the response rates being higher when students were given both time in class to complete it and points for completing it. Students were asked to select their agreement with each of the statements on a 5 point Likert scale from 1 = Strongly Disagree to 5 = Strongly Agree. The responses shown in Table 1 on the following page indicate the percent of students that either agreed or strongly agreed with the corresponding statements. In general, students felt their leaders were knowledgeable and enthusiastic, that they cared about student learning, created an accepting atmosphere, and that they are positive role models. In spring 2017, a question was added to see if students found the LEAP sessions helpful, and most did indeed find it useful. This question was modified in spring 2018 and another question was added to get feedback on the helpfulness of having the LEAP leaders in class. Over 70% of the students feel that their LEAP Leader is a key part of the class learning environment.

In a second paper in FIE 2018 focused on the LEAP facet of our redesigned FYEP, Kemppainen reports student attitudes regarding what they liked about having a LEAP Leader and the LEAP program in general [25]. Additional early analysis of the LEAP program is found in [26].

Table 1: Student feedback about their
LEAP Leaders and the LEAP program

	Fall 2016 n=145	Spr 2017 n=88	Fall 2017 n=761	Spr 2018 n=359
Response Rate	79%	51%	86%	47%
My Leader was knowledgeable about the course content	77%	89%	88%	89%
My Leader was enthusiastic about the subject matter	87%	85%	89%	91%
My Leader displayed a personal interest in students and their learning.	82%	83%	86%	85%
My Leader created an accepting atmosphere	95%	89%	94%	91%
My Leader was a positive role model	89%	86%	90%	88%
LEAP sessions were helpful	-	74%	73%	-
Having LEAP leaders in class was helpful to my learning	-	-	-	82%
LEAP sessions helped me learn course material	-	-	-	77%
I consider my leader a key part of the class learning environment that helped me	76%	71%	87%	83%

C. *Laptop Requirement*

Prior to Fall 2017, there was no computer requirement for matriculating students at Michigan Tech. Approximately 70% of all incoming students however had laptop computers, and between 80-90% of incoming engineering students had laptops. But because there was no general requirement, instructors could not require students to bring their laptops to class.

To encourage a strong sense of "pervasive computing" and the internalization that if a student has a laptop they use for class, then they can do their "homework" anyplace and anytime - this attitude can be called "pervasive computing."

In fall 2017, incoming engineering students were required to have a laptop that met a set of base requirements. The "engineering laptop requirement" held for first-year students in 2017-2018, will hold for first-year and sophomore students in 2018-2019, and so on as a rolling introduction of the requirement. In addition, a preliminary FIE report on the laptop requirement in the context of FYEP was further described and motivated [27].

Students overwhelming report using their laptops outside of ENG1101. More than 85% report they use their laptops for educational or professional purposes outside of ENG1101 every day. (Table 2) Additionally, more than 60% of the students agree or strongly agree that being required to own and use a laptop as an engineering student has helped them become more comfortable using computers. (Table 3)

Table 2:
How often do you use your laptop for educational or professional purposes outside of ENG1101

	Fall 17	Spr 18
Every day	87%	85%
Week days only	5%	8%
Three or four days per	4%	8%
One or two days per week	2%	0%
Monthly	0%	0%
Never outside of ENG1101 assignments	1%	0%

Table 3:
Being required to own and use a laptop as an engineering student has helped me become more comfortable using computers

	Fall 17	Spr 18
Stronly Agree	33%	31%
Agree	39%	31%
Neutral	16%	31%
Disagree	6%	4%
Stronly Disagree	6%	4%

D. *Instructional Materials*

The instructional materials we used included an e-book and an computer application for problem sets and etc. Instructional materials also include locally produced videos, videos from other institutions, and in general the resources of the world-wide web. Focusing on the more traditional items here, the e-book and the associated "lab" app were not viewed at the outset with favor by students. But in this case the support role played by the instructional materials was quickly understood by most students. Logistically, the role the instructional materials play, particularly the "lab" app, was to ease the grading load on faculty. Our scale-up classes are large, approximately 120 students (in 30 work groups). Although the near-peer mentors act as extensions of faculty outreach, still for exam and project grading there is a need for faculty to grade student work.

In fall 2017 we incorporated an electronic textbook, **Thinking Like an Engineer: An Active Learning Approach**. Accompanying the e-book is **MyEngineeringLab** (MEL), which primarily is an interactive homework system that provides instant feedback on assigned problems. Within the problem sets in MEL there are links to corresponding e-textbook pages, hints to solve the problems and a multimedia library of video lectures and solutions. There are three types of problems in these materials: 1) Comprehension Checks which appear within the chapter text, 2) In-Class Activities that are designed to be actively worked in pairs or small groups and focus on material in the current chapter, and 3) Review Questions that often combine current material with that from earlier chapters.

Before each class students were typically assigned one to four of the simple, *Comprehension Check* type problems. As a warm-up during class, students commonly were asked to collaboratively (within their team) complete one to two of the more in-depth *In-Class Activities* or *Review Problems* MEL.

In an end-of-semester survey, students were asked for feedback on various course materials and resources. As shown in Table 4, the students in the fall were dissatisfied with the electronic textbook, with 46% of the students disagreeing or strongly disagreeing with the statement, "I found the E-Text book to be helpful to my learning" and 18% reporting that they did not use it. The dissatisfaction with the book is at least partly due to instructor unfamiliarity with the electronic text and its integration into our Learning Management System (Canvas).

For the initial several weeks the text was only viewable to students inside the LMS page. As a result, it was difficult to read the material, and it required that you scroll around the page. Once we were able to have it load into a new browser tab, it was much easier to read, but by that time, students were in the habit of not using the book. In the spring, students were able to start using the book right away and were referred to specific pages book more often during class activities. As a result, the spring students had a more positive view of the e-text, with only 20% disagreeing or strongly disagreeing, and 12% reporting they did not use the book. On the other hand, students found MEL, the interactive homework system, to be helpful to their learning, with more than 60% of the students agreeing or strongly agreeing to the statement, "I found the *MyEngineeringLab Assignments* to be helpful to my learning" in both semesters.

Table 4:
I found the textbook / MEL to be useful for my learning

Textbook	Agreed	Neutral	Disagree	Did not use
Textbook Fall 2017	19%	18%	46%	18%
Textbook Spring 2018	34%	35%	20%	12%
MEL Fall 2017	62%	22%	16%	0%
MEL Spring 2018	66%	15%	16%	3%

E. Instructional Space

The instructional space was a major hurdle in our path. We unsuccessfully attempted to get a renovation of an existing classroom two years prior. This space did not have a flat floor, and the necessary renovation was very costly. Two years later, we discovered a largely unused space on the garden level of our major residence hall. On inquiry it turned out that this space could be used during 8am-6pm hours for classes in FYEP if we could fund the renovation for furniture and IT work. This is the point at which years of work in EF paid off, and Michigan Tech showed the capability of facing change by realizing an opportunity when it was seen. The open 2200 sq. ft. instructional space was allocated to EF as a long-term loan, and the Michigan Tech administration found the funds to renovate the space.

Table 5:
I found the Wads Annex classroom to be a comfortable learning environment

	Fall 17	Spr 18
Strongly Agree	28%	27%
Agree	53%	50%
Neutral	12%	12%
Disagree	4%	4%
Strongly Disagree	17%	8%

In general students enjoy and use the instructional space. Over 75% of the students agree or strongly agree that the classroom is a comfortable learning space and more than 50% of the students report using their pop-up monitors at their table frequently or almost always. Table 5 documents these results.

F. Systemic View of the Revised FYEP Model

Above we have written a short description of each component of our revised FYEP program, and a sample of very early data about student perceptions of most of the components. Each component plays a distinct role when FYEP is viewed as a system. Each one of the components depends on interaction with other components. The pedagogy drives the program. The instructional space provides a renovated venue in which the pedagogy can "work". The pedagogy depends on the laptop requirement. And so on. The success of our students depends on all of the components working together. That smooth *system synergy* has been and remains a major challenge as we move towards our second year.

V. Programatic Change in FYEP as a ***Change Agent***

The laptop requirement in some ways is a sleeper component when understood in the context of change considerations in our engineering college. Our ME program in particular will immediately reap benefits this year as rising sophomores go into a ME practice environment. We believe, and we will stand ready to help, programs to leverage the presence of laptops in each student's backpack. Perhaps even more, there will be leverage in the attitudes we hope to develop in our students. Of course, any first-year program is only the start of the students' undergraduate experience. But to the extent that FYEP develops and "graduates" rising sophomores who are more open to ambiguity in problem solving, and more willing to work hard to learn what is necessary to solve a given problem, FYEP will act as a positive catalyst in our college towards development of stronger students who are likely to expect the type of learning environment that we are developing.

VI. The Core Research Question on which We Focus

What is the effect of the substantial revision we have made in FYEP? We intend to longitudinally in the coming years in its many sub-questions and sidebars. A related question is: How can we continue to sustain our first-year approach, and how can we help others to adopt it to the extent that is feasible. Both the core "effects" question and the core change/ sustainability question will occupy us for some years to come.

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