Three Years After Rollout: A Report on Systemic Changes in a First-Year Engineering Program

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Jon Sticklen was the chairperson of the Engineering Fundamentals Department, Michigan Technological University from August 2014 through June 2020. In the decade of the 90s, Dr. Sticklen founded and led a computer science laboratory in knowledge-based systems in the College of Engineering, Michigan State University that focused on task-specific approaches to problem-solving, better known as expert systems. Over the last fifteen years, Dr. Sticklen has pursued engineering education research focused on early engineering with an emphasis on hybrid course design and problem-based learning. Dr. Sticklen assumed the chairperson of Engineering Fundamentals at Michigan Tech on August 1, 2014. His research has been supported by a number of companies, as well as by NSF/CISE, NSF/DUE, and DARPA. Specifically, his research in DBER-based engineering education has been supported by NSF/DUE and NSF/CISE.
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Abstract

This report focuses on an overview and preliminary results for a project to update the first-year engineering program (FYEP) at Michigan Technological University (MTU) with an FYEP enrollment base of approximately 1,000 students. We are now three years out from the rollout of an updated FYEP that dates from the fall semester, 2017. The goal we have for this paper is to economically describe at the 10,000-foot level (a) our reasons for the systemic changes we established, (b) the core architecture of our revised FYEP, (c) a selected subset of our preliminary findings and observations regarding our revised FYEP, (d) a special observation concerning the ease of transition from face-to-face operation over to complete internet operation of FYEP while maintaining the integrity of our revised operational model all in the context of a global pandemic (coronavirus), and (e) a thumbnail description of our plans for the future.

Introduction: Framing of the Goals for an Enhanced First-Year Engineering Program.

The common first-year engineering program at MTU was started in the Fall of 2000. This common first year provides students an opportunity to explore the different engineering majors while learning valuable skills for their major and an additional year of flexibility in deciding a major. The classes employed active, collaborative learning methods, and the classroom was redesigned to foster teamwork [1]. Students who were calculus-ready began by taking ENG 1101: Engineering Analysis and Problem Solving their first semester, followed by ENG 1102: Engineering Modeling and Design their second semester. Beginning in 2004, students who were pre-calculus ready took a three-semester course sequence: ENG1001: Engineering Problem Solving, ENG1100: Engineering Analysis, followed by ENG1102 [2]. Beginning in Spring, 2015, initial planning and exploration were begun to determine possible next evolution points for the FYEP.

The stakeholders for the FYEP are the first-year engineering students, the faculty of the various engineering majors in our college, and the Dean of the College of Engineering. The Engineering Fundamentals Department (EF) faculty who actively teach the FYEP courses assess the impact of any changes. It is important to note that the retention rate from the first to the second year within our college hovers between the high 70s and low 80s, which on a national scale are good results, although we continue work to increase our retention. Stakeholder needs will be assessed in a future longitudinal study examining student success in their chosen major. An interim assessment of meeting needs of students was placed on student-reported satisfaction. An important facet of FYEP is to help students find the most appropriate major for them, including the possibility that a major outside of engineering may be the best choice from a student's viewpoint.

Broad directions for change in FYEP client departments were determined through a series of individual conversations with the chairpersons in the College of Engineering starting in spring 2015 and extending through the spring of 2017. The overarching composite response focused on
the need for: (a) enhanced broad problem-solving skills including open-ended problem solving, (b) enhanced awareness and competencies in computational problem solving, (c) enhanced strengths for developing a life-long learner mindset, and (d) continued attention and rigor in topics already in the FYEP courses, such as "unit analysis". The development of a response to these consensus items very clearly could not be simply added to our existing curriculum for first-year engineering, noting that a typical student complaint about the coursework topics seemed too disjointed and too packed. In Fall 2015, after discussions with the Dean of Engineering, the Dean's support for an initial effort to extend FYEP to better meet these goals was in concept agreed to.

The Architecture of the Enhanced FYEP

Our major operational path to reaching our goals for the revised FYEP was (a) streamlining and integrating our first-year engineering topics, (b) moving to a 100% inverted classroom delivery model, (c) introducing a requirement of student-owned laptop computers, (d) moving the bulk of our class time with students to a newly renovated, "scale-up" type instructional space, and (e) instituting a near-peer mentor program. Figure 1 shows the major subsystems of the enhanced FYEP. Following is a bulleted explanation of Figure 1.

- The **Learning Space Upgrade** was one of the most difficult subsystems for FYEP to orchestrate. We needed typical studio space as epitomized in the SCALE-UP projects described in reference [3]. We identified a space of approximately 2200 sq. ft. that was under-utilized in the garden level of our main residence hall. We were enabled by an internal grant to both renovate this space and to equip it with 15 work tables, each with a capacity of 2 work teams of 4 students each, with an overall capacity of 120 students.

- The **Laptop Requirement** for the College of Engineering was key to the success of the enhanced FYEP for two reasons. First, it would have been difficult to fund the necessary fixed computing equipment to provide each student with an in-class computer. Much more importantly, we continue to foster a "ubiquitous computing mindset" in our first-year students. Survey results from Fall 2015 indicate that 92.5% of our first-year students have a laptop or desktop computer for their personal use [4]. Approval for the Laptop Requirement for the College of Engineering required a stakeholder committee of University Admissions, University Financial Aid, Information Technology, and EF. The Dean of Engineering was a strong catalyst for the approval of the laptop requirement, which went into effect in Fall 2017.
The *Near-Peer Mentor Program*, LEarning with Academic Partners (LEAP) Program, features a cadre of 45-55 students who have taken the target courses and performed well, and possess good interpersonal communication and mentoring skills. These are not volunteer positions, but regular undergraduate student work positions. The LEAP Program was conceived to give students the sense of a small class in the midst of a physically large classroom with a ratio of one LEAP Leader for a group of 20-24 first-year students. A total of 5 LEAP Leaders would be present in our classroom of 120 students. The LEAP Leaders attend class and assist with in-class activities, grade assignments, and plan and facilitate a 50-minute LEAP Session once a week [5]. In this LEAP Session, the leaders focus on facilitating activities to help the students master the more challenging course concepts.

The *EF Faculty* teach the sections of the 120 person first-year engineering courses and are supported by the LEAP Leaders in their sections.

All of the above bullets play a role in enabling the *inverted classroom delivery model*, in particular, the ability of teams of four to be effective collaborators in problem-solving and in learning generally. The topics for our first semester courses are structured by computational topics, which are mostly topics in a learning progression for beginning MATLAB, read from left to right side of the tree shown conceptually in Figure 2.

**Results and Observations to Date**

Our assessment for the reboot of our first-year engineering program has been systematic from rollout. Thus far, assessment has focused both on attitudinal and direct student outcome measures. The attitudinal assessment has demonstrated strong student acceptance for (a) our near-peer mentoring program, (b) the revised learning space, (c) the laptop use as an integral part of the first-year experience, and, to a lesser degree but still positive, for (d) the inverted delivery model. These results are summarized below.

At the end of each semester, students have the opportunity to evaluate their instructors, their LEAP Leaders, and their engineering course through the end-of-term surveys administered by our Center for Teaching and Learning. In Fall 2019, 88% of the students in all the first-year engineering courses completed this end-of-term survey (n = 820). Seventy-nine percent of the students who responded to the survey found they have benefited from attending the LEAP sessions, 83% found that these sessions helped them learn the course materials, and 88% found that having a LEAP Leader in class was helpful to their learning.
Students in ENG1101 are also asked to provide their feedback about the classroom, their laptop use, and how useful various course components and resources are to their learning on another end-of-term survey delivered through the course Learning Management System (LMS). Students were given time during the last class to complete the survey and homework points were given for completing the survey. An identical survey was given in Fall 2017 and Fall 2018. There were several changes made to the Fall 2019 survey. The response rates were 69.6% in Fall 2017 (n = 791), 89.8% in Fall 2018 (n = 766), and 74% in Fall 2019 (n = 769).

As shown in Table 1, most students seem to be happy with the revised classroom, with more than 80% of students either agreeing or strongly agreeing with the statement, “I found the classroom to be a comfortable learning environment.” There are some students, less than 10% that disagree. In response to the prompt, “The thing that least excited me in this course …” one student commented, “The really crowded and loud room. It made me feel really crabby and anxious and I couldn't focus during the class period.”

The student-owned laptop initiative has allowed every student in the class to be actively engaged in every activity. Prior to the requirement to have a laptop, students shared a university-owned desktop computer or brought their own laptop with them to class. During years before 2017, typically one or two computers were available to each team of 4-5 first-year students. As shown in Table 1, more than two-thirds of the students agree or strongly agree that “Being required to own and use a laptop as an engineering student has helped me to become more comfortable using computers.” This comfort is likely due to a high frequency of computer use by the students. In response to the question, “How often do you use your laptop for educational or professional purposes outside of ENG1101,” more than 90% of students report using their laptop five or more days per week and all students report using their laptop at least one or two days per week outside of class.

Student acceptance of the completely inverted learning environment has not been as strong as some of the other subsystems; however, there has been a steady improvement in this each year as shown in Table 1. In Fall 2019, more than 55% of the students agreed or strongly agreed with the statement, “I think the teaching model (prepare before class, solve problems in class using what I learned) helped me to learn because it made me responsible for my own learning.” This is an increase of nearly 20% from the Fall 2017 responses.

Another measure of student satisfaction with the overall revision of the first-year program is reflected in the end-of-term course evaluations. The overall average responses for the questions on the course evaluations are shown as a function of time in Figure 3. An average was calculated for

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<th>Table 1. Student Satisfaction with the Renovated Studio Space, Their Comfort Using Their Laptops, and Their Satisfaction with the Teaching Model</th>
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responses on the following topics: (a) instructor enthusiasm, (b) clarity of instructor communications, (c) encouragement by an instructor to participate during the in-class time, (d) encouragement by an instructor to participate in class prep, reflection, and other outside-class activities, (e) appropriate use of technology by the instructor. Responses were on a 5-point Likert scale, ranging from Strongly Disagree = 1 to Strongly Agree = 5. Responses from all sections of ENG1101 were averaged. During Fall 2016, three sections of ENG1101 (183 of 927 students) piloted the revised course and were not included in the Fall 2016 responses. As expected, the average responses dropped drastically during the first semester when the revised course was rolled out at full scale (Fall 2017). However, it is also clear that these measures have recovered and in Fall 2019, are now close to their pre-revised levels. Examining the six measures individually reveals that communicating course material effectively is lagging recovery to expected levels. This is likely due to our extensive use of our LMS and apps that integrate with it which can be overwhelming for first-semester students.

Unanticipated Event and Flexibility in Our Instructional Model: The Global Pandemic

There is one additional observation that is critical for our program going forward. The global pandemic caused by the global-scale spread of the novel coronavirus. Like most other U.S. universities, MTU converted to 100% online instruction; for us, the change over thankfully took place in our Spring Break and we accomplished the transition in less than one week. For FYEP, largely due to our instructional model, our conversion to synchronous, online classes run with ZOOM was conceptually straightforward. Our enhanced instructional system was the same in concept in the face-to-face operation and in the totally on-line operation. The two different environments simply required differing implementation. ZOOM is MTU’s tool of choice for teleconferencing. Communication to/from the highest level in the section between the instructor and the section LEAP Leaders and from the instructor to the students was the chief hurdle. The facet of ZOOM which we, in general, relied on was the ability to have a ZOOM class session in which teams were sent to ZOOM breakout rooms to work on the problem set or the discussion topic of the day. The glue that really propels FYEP is the LEAP program. Making effective use of the breakout rooms largely fell on the shoulders of the LEAP Leaders of the program.

We put together a hasty research pilot study during our online experience to gauge the level of connectedness students experienced in FYEP classes online versus face-to-face. Connectedness
leads to student engagement, and student engagement leads to enhanced student learning [6]. Preliminary analysis of data collected at the start and the end of the online, second half of the Spring Semester seem to show that students in FYEP perceived no significant difference between the level of connectedness to other students and to the FYEP course than they felt in (a) our pre-coronavirus, face-to-face environment and (b) the connectedness they felt in our post-coronavirus, online environment. We intend to further investigate this observation.

**Next Steps**

Over AY 2020-2021, it is likely that MTU along with most others will need to be mostly online again at some point. Thus the most pressing issue for us to work out how to best serve our FYEP students from an online platform, and to further triage how to make our transition from F2F to fully online, or vice versa as turn-key as possible. We plan to report on our progress toward our overarching goals of our First-Year Engineering Program: (a) enhanced broad problem-solving skills including open-ended problem solving, (b) enhanced awareness and competencies in computational problem solving, (c) enhanced strengths for developing a life-long learner mindset, and (d) continued attention and rigor in topics already in the FYEP courses in a future paper. We also intend to undertake direct comparisons between students outcomes prior to our program reboot and after the reboot. The learning goals we set for the new program differ from the prior outcome goals. Hence we will need to treat Before/After comparisons very carefully. In the long story, our next large task is to undertake a longitudinal study through engineering degree programs to determine the effect our enhanced FYEP is having on the BS degree graduates of Michigan Tech.

**References**


