IUSE: A Re-imagined First-Year Engineering Program—FYE2.0

Abstract
Purdue University established Freshman Engineering (now known as First-Year Engineering) in 1953, the first program in the U.S. to do so. Over the years, First-Year Engineering (**FYE**) programs have been established at several institutions, but not all, across the country. In the early 1990s, the National Science Foundation (**NSF**) provided funding for what were called the Engineering Education Coalitions. They funded a total of eight coalitions that involved more than 40 institutions of higher education over the period from 1990-2005. In addition, NSF created the Action Agenda program in the late 1990s aimed at individual institutions that wanted to adapt and adopt the findings from the existing Coalitions. A strong focus of the Coalitions was on introductory engineering courses, with the rationale that engineering was losing too many students through attrition, and we needed to pay more attention to their formative years. Nearly every Coalition created some version of an FYE program through this funding mechanism. The number of FYE programs across the nation has increased dramatically based on these investments, largely in response to curricular efforts aimed at retaining engineering students by providing them with meaningful career-oriented experiences early in their college educations.

Many of these first-year programs were called "common first-year engineering programs," meaning that all students enrolled in the same courses at the same time. It is a one-size-fits-all, cookie-cutter approach to education. Despite the laudable goals espoused by most FYE programs, there has been an unintended consequence: curricular rigidity and inflexibility. Thus, students have little agency to shape their own pathway toward an engineering degree. Recently, a midwestern R1 institution obtained a grant from the NSF to develop the next generation of first-year programs: FYE2.0. We envision a modularized program will provide students with essential skills, while at the same time scaffold their first year with opportunities for customization and flexibility in charting their own engineering journey. This paper outlines the logistical progress made in implementing FYE2.0 to date and discusses plans for the future.

1.0 Background

First-year engineering programs (FYE) are a common way for students to be introduced to the engineering profession. [1]. FYE programs typically include one or two introductory courses on a variety of topics. The content of FYE courses can include any combination of topics such as design, communication, professional skills (e.g., teamwork, leadership), and engineering specific technology/tools (e.g., MATLAB, CAD) [2]. Fostering interactions between first-year students and faculty/upper division engineering students have been shown to aid in the retention of engineering students. The goals of FYE programs are typically:

- Provide FYE students with opportunities to get to know *engineering* faculty and upper-division *engineering* students to foster a sense of belonging in engineering.
- Help students develop the professional and technical skills they will need for their futures.
- Provide students with an understanding the engineering profession since many have no idea what engineering entails.
- Implement evidence-based pedagogies, to improve learning and reduce attrition.

In general, design in the first year is considered to be particularly well-suited to giving students a "taste" of engineering, to excite students about engineering careers, and to provide students with the chance to interact meaningfully with engineering faculty and peers. A semester-long design project is often viewed as one key to integrating all these attributes and is included in most, if not all, FYE programs.

1.1 Curricular Complexity
The potential range of content present in FYE introductory courses is vast, and there is little consensus about which foci are most crucial in developing effective first-year courses. Typically, FYE programs use a cookie-cutter approach to education—all students come in with the same preparation. Some FYE programs assume that all students are ready for Calculus and are enrolled in it simultaneously with the first-year courses. In fact, in some FYE programs, Calculus is either a pre- or co-requisite course and thus may become bottlenecks to student progress [3]. For example, starting in Calculus in the first semester predicts successful in completion of an engineering degree [4]. FYE courses that depend on students being Calculus-ready, whether explicitly [5] or implicitly, can hinder student progress towards graduation. The problems are most apparent for community college transfer students, because many FYE courses are not equivalent to those at community colleges or peer institutions and represent significant additions to time to degree [6]. When curricula become too internally linked in a prerequisite structure, meaning the curriculum's "complexity" increases, completion rates tend to decrease [7, 8]. Therefore, there is substantial value in questioning how we might make the gateway into the disciplines less rigid.

2.0 Our Current Context
The University of X is an R1 institution that annually enrolls approximately 1200 FYE students; our dean has articulated a target of 2,000 FYE students per year by 2030. All FYE students are required to take a two-course sequence, Foundations of Engineering Design Thinking 1 and 2. Course learning outcomes focus on introducing students to engineering, developing an engineering way of thinking, and preparing them for subsequent engineering courses and work experiences. Specific topics include engineering design thinking, algorithmic thinking, spatial thinking, problem-solving, and disciplinary engineering principles. The courses include a major design project each semester. In addition, instruction in a number of "modern tools" is part of the course structure, including LabView, MATLAB, Python, and Visual Basic.

Content in the two-semester FYE courses at University X is delivered through evidence-based pedagogies: a flipped classroom format with collaborative learning. The courses include semester-long Robotics design projects. There are weekly homework assignments and mid-term/final exams. Upper division engineering students and graduate teaching assistants aid the faculty member in supporting students through the courses.

The current format of the two 3-credit hour courses, which cover a broad range of topics, makes it challenging for a student transferring into engineering from a different institution to receive credit for either or both of the FYE courses. From 2021-2023, the department committee that evaluates transfer credit applications for the FYE courses has granted 11 of 72 petitions for the first course and one for the second course. Three additional transfer students received course credit through a further petition to consider other courses along with the first-year courses they had completed at their previous institution. [For example, a separate computing course in their major's curriculum could be used along with their previous FYE course to obtain credit.] Students who do not receive credit for either FYE course must enroll and complete the two courses successfully. Passing the second course is required for co-op placement in the second year, so not successfully completing this course extends the time to graduation for many students. This challenge is not unique to University X; as noted previously in this paper, FYE courses across the US have a variety of formats, topics, and credit hour requirements [9].

3.0 Curricular Vision
In May 2024, PIs at University X received a grant from the National Science Foundation to implement a second generation first year program, FYE2.0. Ultimately in FYE2.0, we envision that each student will complete a combination of 0.5-1 credit-hour modules to achieve a total of 6 credits (the number of credits

in our current program). Our design for FYE2.0 includes two core 1-credit modules, one for each of the first two semesters of a student's degree plan. These core modules will be required for all students and will include a teaming experience and completion of a design project. In addition, students will select elective modules of 4 additional credits. Elective modules will likely be organized by theme (e.g., computational tools, graphics and CAD, professional skills, etc.), and students may be required to take one or more modules from certain "themed" lists. We anticipate that FYE2.0 will remove a significant obstacle for transfer into engineering by helping students who matriculate from another institution determine which of our modules they have satisfied and not need to repeat FYE courses they have already completed.

4.0 Progress to date

Various members of the PI team have met with advisors, admissions counselors, administrators, departmental curriculum committees and faculty to discuss program plans and obtain their feedback and insights. The concept of modularization has been approved by all of the necessary entities in the college including the college curriculum committee and a majority of the various programs in the college. In addition, a vote of the faculty of the college was positive.

In the first year of the project, there have been no student-facing changes to our current FYE program. We have tested a few modules in the existing courses and made changes to our design project, but students are still enrolled in two 3-credit courses that include various tools and topics. Our plan for next year is to offer the modularized 1-credit engineering design project courses each semester as separate entities. In addition, we will offer three versions of a 2-credit engineering problem-solving course each semester. Thus, students will enroll in the design project course and one "flavor" of the problem-solving course for a total of 3-credits each semester. Table 1 includes rough outlines of the various 2-credit courses that will be offered in the fall semester. Note that the topic order could vary by version.

Table 1. Versions of the Fall Semester 2-credit Problem-Solving Course

Version 1		**Version 2**		**Version 3**
Spatial Thinking		Spatial Thinking		Spatial Thinking
Flow Diagrams		Flow Diagrams		Flow Diagrams
Intro to Python		Intro to Python		Intro to Python
CAD-Solidworks		Adv. Python		Adv. Excel

Our original plan was to allow departments to specify 2-3 required modules; however, as we have worked with the various constituencies in the college, these plans have been modified somewhat. After discussions with the program representatives, students will be able to specify the number of modules they will require from a given category but will accept others from that same category if students change majors. For example, if a program requires Python, but a student completes MATLAB instead, they will not be required to go back and also complete Python. However, if the student decides that they would *like* to complete Python (in addition to the MATLAB they have already completed), they will be able to do so. Adding a half-credit module to a person's schedule shouldn't be too onerous. In fact, we anticipate that as students throughout the college complete Co-op rotations, they may decide they *want* to complete a specific module (e.g., Visual Basic) in a just-in-time fashion. The modular structure will enable them to easily accomplish this kind of personal learning goal.

Some modules might be universally required by all of the programs in the College. For example, it seems like nearly all of the programs are thinking about requiring Python and perhaps Spatial Thinking modules. We could combine those two half-credit modules into a 1-credit module or even create a 2-credit course that includes the design project, Python, and Spatial Thinking; however, this might make our curriculum too rigid again and defeat the purpose of modularization for transfer flexibility. These are decisions we will be making over the coming year.

5.0 Future Plans and Conclusions

Our modularization efforts to date have primarily been focused on modularizing the content of our current courses. For next year, we intend to continue modularizing content but will also solicit ideas for new modules on entirely new content to offer students the opportunity to customize their credentials according to their interests. Some potential topics for modules on new content include: geometric dimensioning and tolerancing, technical communication, the history of engineering, or climate change. Departments have also expressed an interest in offering a module on their particular discipline, e.g., Intro to Civil Engineering, etc.

Other options we are considering for our FYE2.0 programs include differentiated instruction based on student skills and abilities. For example, if Python is a requirement for students in a given program, those students who have previous programming experience might be able to complete an asynchronous, online module to satisfy this requirement; whereas, those students with little to no programming experience could enroll in a face-to-face version of the course, where they would be supported by the faculty and peer TAs as they are learning the material.

Another option we are considering is having multiple versions of design projects each semester. Currently all of our students complete the same design project and levels of interest in the project topic varies greatly among students. In our modularized FYE2.0, we could offer several different design projects and students could enroll in the section that is completing a project that they are interested in working on.

At University X, we are in the process of revamping our FYE program so that it is more flexible for all of our students, particularly our transfer students. Over the first year of the project, we have gained the necessary approvals to implement such a change and will be implementing a partial modularization over the coming year. Ultimately, we plan to have our entire FYE program modularized for the benefit of students and faculty. Stay tuned.

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