FYE 2.0: Re-envisioning the First-Year Engineering Curriculum

Abstract:

This Complete Evidence-Based Practice Paper focuses on the topic of Curriculum and is based on work funded by an NSF IUSE Grant (#2337003). Specifically, it discusses the efforts at the University of Cincinnati, a large, midwestern, urban university, to update their first-year engineering curriculum by providing students and programs more freedom to select content that will both better prepares students for their upper-division classes and specifically allow the students to pursue topics that are of interests to them. The desire to embark on this re-envisioning of the first-year curriculum is motivated by the demands of industry and the current generation of students, which requires a more flexible approach to allow students to better engage with the field of engineering and to allow curricula to adapt to the ever-changing landscape of engineering practice and technology. The significant curricular change involves taking the current 6 credit hours of first year engineering courses and breaking them into a set of 1 credit (or less) modules from which students can select. This paper discusses in detail the first year of the project which has involved implementing changes to the current courses to prepare for the change to the modular format along with getting buy-in from the administration and faculty within the college. The paper also discusses outcomes from the changes implemented during the first year of the project along with the plan for the second and third year of the project, with the goal of having a completely modularized first-year engineering course structure by the start of the third year.

Background:

A First Year Engineering (FYE) 1.0 program is one of the more popular models used by institutions of higher education around the U.S. for introducing students to the field of engineering and facilitating the transition into their chosen discipline [1]. The primary component of most of these programs is an introductory engineering course or sequence that contains a variety of topics important for general engineering practice and matriculation in an engineering degree program, such as design, communication (i.e., written, oral, and visual), global interest topics (e.g., grand challenges), professional skills (e.g., teamwork, leadership), academic advising, mathematics skills, introduction to the engineering profession (e.g., professional societies, types of engineering, ethics), and engineering specific technology/tools (e.g., MATLAB, CAD) [2]. Additionally, interactions between first-year students and both faculty and upper division peers have been found to positively impact retention of students in engineering programs. The goals of a typical FYE 1.0 programs are to [2]:

- Provide students the opportunity to interact with engineering faculty and upper-division engineering students to improve their sense of belonging in the engineering discipline.
- Help students develop the skills they will need to succeed in their future engineering studies and careers.
- Provide students with an understanding of what engineering "is" since most students do not have this understanding from their high school years.
- Practice evidence-based pedagogies, such as active and collaborative learning, to foster student learning and improve retention in the major.

While FYE 1.0 introductory courses are common at most institutions of higher education, there is still little consensus about which foci are most crucial in developing effective first-year courses. The structure of most FYE 1.0 programs also does not accommodate students who may have different starting points or learning trajectories. One often overlooked aspect of FYE 1.0 programs is how the introductory engineering courses relate within the curriculum to complementary courses (mathematics and science) in the first year as well as courses later in the curriculum. The arrangement of these experiences – called curricular design patterns – can become bottlenecks to student progress [3]. For example, the ability to place into Calculus is a significant predictor for completing an engineering degree [4], so introductory courses that rely on students being Calculus-ready, whether explicitly through prerequisite relationships [5] or implicitly through instruction, can block students from progressing into fundamental courses such as Statics and Circuits. These barriers become highly problematic for transfer students, as many courses available at local community colleges or even peer institutions are not viewed as equivalent to similar courses at the transfer institution and thus result in delays to degree completion [6]. When curricula become too internally linked in a prerequisite structure, meaning the curriculum's "complexity" increases, completion rates tend to decrease [7, 8].

Most current FYE 1.0 programs were developed during the 1990s or early 2000s. However, students today are vastly different from those of 20-30 years ago. Most students who will be entering directly from high school into college in the US in 2024 were born in 2005 or 2006. In their lifetimes, these students have been immersed in an increasing array of technology, including smartphones, social media, Google, YouTube, Instagram, Alexa/Siri, and now ChatGPT. Most saliently, during a critical time in their growth as young adults, they experienced the isolation and online education brought on by the COVID-19 pandemic, which "set back Gen Z — academically, emotionally, and financially" [9, p. 21]. Pre-COVID research about this generation indicated that they "like independent, self-paced learning, with opportunities for collaboration as needed." [10, p. 116]. Even post pandemic, lack of choice and inflexibility is not attractive to this generation of college students, and traditional FYE 1.0 programs do not allow them to personalize their degree as they develop into professionals. Recommendations for institutions of higher education include "(1) Prioritize belonging and purpose; (2) Focus on emerging careers to cultivate student demand; (3) Think about 30 years, not just four; (4) Invest in student engagement in the classroom; (5) Help prospective students find their fit; and (6) Connect student data across campus services" [9, pp. 28-29].

This paper describes our current efforts to implement a modular first-year engineering program (FYE 2.0) that better meets the needs of today's students, faculty, and future employers with emphasis on the following efforts:

- Developing, piloting, and evaluating modules on various engineering topics within a FYE 1.0 class structure with the goal of translating them into a FYE 2.0 modular structure.
- Building consensus and engaging in logistical planning/implementation with faculty, staff, and administrators in the College and other relevant units at the University in support of FYE 2.0.
- Investigating the impact of FYE 2.0 on persistence, preparation, and ease of transfer.

Current Courses

The University of Cincinnati (UC) is an R1 institution that annually enrolls approximately 1300 FYE students. All FYE students are required to take a two-course sequence, Foundations of Engineering Design Thinking 1 and 2, which are housed in the Department of Engineering and Computing Education and typically taken in the fall and spring semester, respectively. Both courses are 3 credit hours, yielding a total of 6 credit hours of FYE coursework. The 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. In addition, UC was the first university in the US to require co-ops in the curriculum (starting in 1906). With co-ops as a pillar of UC's heritage, engineering majors must engage in five co-op rotations before graduation, beginning as early as the fall semester of their second year. Thus, the FYE courses at UC are crucial in preparing students to enter the workforce and have the technical and professional skills to run projects, solve complex problems, and work in a team environment.

Content in the UC FYE two-semester course sequence is delivered through two active learning pedagogies: a flipped classroom format with collaborative learning predominating during class time and project-based learning in the form of a semester-long robotics design project in each of the two semesters. In general, design in the first year is considered particularly 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 peers and faculty. A semester-long design project is often viewed as one key to integrating all these attributes. Specifically in these courses, students apply a design model (empathize, define, ideate, prototype, test, implement) to develop their solution. Through the projects, students also get active practice with concepts such as project management, teamwork, professional ethics, systems thinking, and computational tools (e.g., LabVIEW, Python, and Excel). Individual student mastery of course content is assessed through weekly homework assignments along with three exams each semester. Peer teaching assistants (engineering majors in their second year or beyond) and graduate teaching assistants aid the faculty member in supporting students through all aspects of the courses.

Table 1 shows how topics in the Foundations of Engineering Design Thinking 1 and 2 courses are already positioned to be conceptualized as modules. The layout shown in Table 1 is for the 2023-2024 academic year. Throughout the year, students focused on the engineering design process and algorithmic thinking (via flow diagrams and computational tools such as LabVIEW and Python). They use LEGO Mindstorm kits to design, build, and program (using LabVIEW) a walking robot capable of picking up and moving objects. The second course provides brief introductions to content that students will experience in-depth during their second- or third-year classes – mechanics, electricity, material/energy balance, and statistics (3 class meetings each) – along with introductions to MATLAB and Visual Basic for Applications (VBA) in Excel. This second course also has a robotics project (with Python as the coding language). Students in both courses build professional skills such as teamwork, project management, and ethical practices. In

Table 1, the "Credit Hours" column lists approximations for the current distribution of credit hours among the topics and total 3 credits for each course.

Table 1. Topics in the FYE Courses (2023 – 2024 academic year) Positioned to be Converted to Modules

Module	Credit Hours	Topics
First-Semester Foundations of Engineering Design Thinking 1 course (Fall 2023 and prior)		
Engineering Design 1	1	Design, teaming, project management, ethics
Engineering Principles/Tools	0.25	Excel, Measurements, Estimations, Dimensions
Spatial Thinking	0.5	Isographic, orthographic, rotations, symmetry
Computational Tool 1	0.25	Flow Diagrams
Computational Tool 2	0.5	LabView
Computational Tool 3	0.5	Python
Second-Semester Foundations of Engineering Design Thinking 2 course (Spring 2024 and prior)		
Engineering Design 2	1	Robotics and additional Python
Computational Tool 4	0.5	MATLAB
Computational Tool 5	0.5	VBA
Statistics	0.25	Descriptive, inferential and central limit theorem
Mechanics	0.25	Resultant & reaction forces, strength of materials
Electricity	0.25	Circuit components, circuit analysis, capacitors
Material/Energy Balance	0.25	Batch and rate processes, energy and work

Modularizing the Current Courses

To begin the transition to the fully modular format, during the 2024-2025 academic year, the current courses were rearranged and modified from the 2023-2024 academic year. Table 2 lays out the 2024-2025 course topics along with the estimated credit hours for each topic. From a content standpoint, Python was completely covered in the first course and LabVIEW was moved to the second course. LabVIEW was then utilized in the robotics project in the second course. The project in the first course was changed to require students to develop a product for a population in need. The project was implemented in two phases. During the first phase, students worked in teams to identify a population for which they wanted to develop a solution and researched what needs that population had. Phase 1 culminated in a proposal for a solution that would address an identified need. As a part of this proposal, students were required to identify a set of data and provide some rudimentary modeling to help predict the potential impact their solution might have on their targeted population. During Phase 2, the teams transitioned to a building and testing modality. Each team was required to develop a prototype of some kind (computational or physical) that allowed for the testing and verification of at least one significant criteria/specification of the proposed solution.

Additionally, in the first course, more time was provided in class for students to work on their projects and learn about topics related to the project (Teaming, Ethics, Basic Excel, Measurements, Estimations and learning about the Design Process). Besides the addition of LabVIEW for the robotics project, the second course remained relatively unchanged.

Table 2. Topics in the FYE Courses (2024 – 2025 academic year) Positioned to be Converted to Modules.

Module	Credit Hours	Topics
First-Semester Foundations of Engineering Design Thinking 1 course (Fall 2024)		
Engineering Design 1	1	Design, teaming, project management, ethics
Engineering Principles/Tools	0.25	Excel, Measurements, Estimations, Dimensions
Spatial Thinking	0.5	Isographic, orthographic, rotations, symmetry
Computational Tool 1	0.25	Flow Diagrams
Computational Tool 2	1	Python
Second-Semester Foundations of Engineering Design Thinking 2 course (Spring 2025)		
Engineering Design 2	1	Robotics and LabVIEW
Computational Tool 3	0.5	MATLAB
Computational Tool 4	0.5	VBA
Statistics	0.25	Descriptive, inferential and central limit theorem
Mechanics	0.25	Resultant & reaction forces, strength of materials
Electricity	0.25	Circuit components, circuit analysis, capacitors
Material/Energy Balance	0.25	Batch and rate processes, energy and work

For the 2025-2026 academic year, the two 3-credit courses will be split into a 1-credit Engineering Design 1 course in the fall semester and a 1-credit Engineering Design 2 course in the spring semester. The motivation behind this is that these two 1-credit Engineering Design courses are part of the long-term vision for the modular format and this content is already set to be spun out into separate courses based on the work accomplished during the 2024-2025 academic year. The remaining four credits will be split into a 2-credit Engineering Applications 1 course in the fall and a 2-credit Engineering Applications 2 course in the spring. This will be a temporary hold for year 2 of the NSF project with the goal of converting these courses into 1 credit or 0.5 credit modules by the following year. The Engineering Design course will meet once a week for 2 hours. During that time, students will be introduced to a variety of topics to assist in their project and have time to work on their project in class. Each section of the Design course will be mapped to a section of the 2-credit Engineering Applications course to help simplify registration.

The 2-credit Engineering Applications 1 course in the fall will include a Spatial Thinking module, a Flow Diagrams module, and an Intro to Python module. Students will then have the choice of taking a final component worth 0.5 credits focusing on either Advanced Python, CAD, or Advanced Excel. These topics were decided upon based on discussions with our degree granting programs. Most programs wanted their students exposed to Spatial Thinking, Flow Diagrams and Python, which resulted in having 1.5 credit hours of overlap. For the Spring Semester, the 2-credit Engineering Applications 2 course has not been fully laid out. Table 3 shows a possibility for this course. However, further conversations with the degree-granting programs will take place before finalizing this plan. Some programs have shown interest in the MATLAB module, but not all of them. Also, the VBA module has been recommended by our engineering student government, since a majority of students use Excel on co-op, and VBA has proven to be an incredibly useful tool during co-op rotations. The second course will possibly offer a choice of modules that prepare students for their second-year courses (Statics, Electricity and Material Energy Balance). We also anticipate all students taking the statistics module since it is important to the Testing phase of the Design process and a topic covered in all our programs.

Table 3. Topics in our FYE courses (2024-2025 academic year) positioned to be converted to modules.

Module	Credit Hours	Topics
First-Semester Foundations of Engineering Design Thinking 1 course (Fall 2025)		
Engineering Design 1	1	Design, teaming, project management, ethics, Excel, Dimensions, Estimations, Measurements
Engineering Applications 1	0.5	Spatial Thinking
	0.5	Flow Diagrams
	0.5	Python
	0.5	Choice: CAD, Advanced Python, or Advanced Excel
Second-Semester Foundations of Engineering Design Thinking 2 course (Spring 2026)		
Engineering Design 2	1	Robotics and LabVIEW
Engineering Applications 2	0.5	MATLAB
	0.5	VBA
	0.5	Statistics
	0.5	Choice: Mechanics, Electricity or Material Balance

Starting in year three of the project (2026-2027), we plan to further break down the two Engineering Application courses into 1 credit or 0.5 credit modules. Currently, UC does not have a mechanism for offering courses with less than 1 credit per course, so there is no option to go to 0.5 credits. We have been working with administrators in our university's Office of the Registrar to make this happen. If we go to the 0.5 credit modules, then Table 3 could be representative of the classes that would be offered. If the minimum credit for a module is 1, we will pair the choice module with one of the other 0.5 credit modules, which is not ideal and may require us to look at the timing of the Spatial Thinking and the Flow Diagram module.

Also, going into year 3, we anticipate having created a series of new modules that would help further spark student interest and better prepare them for the ever-changing workforce. These modules could include a module on Artificial Intelligence (AI), Cybersecurity, Design Modalities, Life-Cycle Analysis, Sustainability in Engineering, etc. We also anticipate creating modules which are a deeper dive into some of the content we plan to offer in the 2025-2026 academic year (advanced CAD, graphics, advanced computational tools, computational modeling). The other modification will be to the second-year topic courses (Statistics, Statics, Electricity and Material/Energy Balance). Currently these topics are covered for two or three class periods, and very briefly. The hope is to develop modules of these that are more in depth and last at least 4 class periods to reach 0.5 credits, with each class lasting 110 minutes.

Modular Development

To achieve this project's goals and ensure widespread faculty buy-in, we are involving all faculty in the college in the curricular reform process. In March of each project year, faculty will be invited to submit mini-grant applications (2-3 pages) to develop modules for the FYE 2.0 program. During the first year of the project, the modules were created by faculty in our department (which houses the current courses). Starting in March of 2025, we will be soliciting proposals from faculty in the other departments within the college. Each mini grant provides a summer salary stipend; specific dollar amounts vary based on the "Effort to Modularize." Each mini-grant application must include a plan for assessment and dissemination and strategies to address issues of diversity and access. Curricular parameters for the modules will also be developed, covering attributes such as resources and pedagogy, so the modules are not strictly lecture-based instruction. The project's senior personnel and members of an Internal Advisory Board will review mini-grant applications and make funding decisions based on the need for certain topics at that point in the project and to ensure a broad variety of topics are available to students. Funding for a minimum of 21 mini grants has been included in the project budget.

The external evaluator for the NSF project will collect data to understand the implementation and outcomes of the modules, with special attention to student feedback about the modules and the logistics of implementing the modular approach to FYE. The evaluator will also work with each module developer to identify performance data to be collected to evaluate the learning taking place within the module in addition to the attitudinal data. The evaluator will gather data to inform the project team through surveys, interviews, and focus groups conducted with students and peer teaching assistants to understand satisfaction with module content (within each module and across the modules selected throughout their FYE), scheduling, instructional strategies, recommendations for module combinations, and preparation for later courses. The evaluator will prepare short memos at the end of each semester so that student feedback and recommendations can be quickly acted upon. This quick cycle reporting will ensure that evaluation findings inform project activities to support robust outcomes.

Course Approval and Buy-In

The plan described previously to go from two 3-credit courses to a modular format has been developed through a long process involving both the initial crafting of the proposal to NSF and continued refinement as we met with different stakeholders during the first year of the project. Table 4 lists the groups of people with whom the project team met and roughly when the meetings took place. The project did not get officially funded until May of 2024, but by March it was pretty clear (barring any funding holds) that the project would get funded. At that time, we began meeting with the different stakeholders. For clarity, University will refer to the entire University, College refers to our College of Engineering and Applied Science, Department refers to the department housing the FYE program, departments refer to any other department within the College, and Program refers to the degree-granting undergraduate programs within the College. The funded project has an advisory board which will be described shortly and is noted as FYE 2.0 Advisory Board.

Table 4: List of meetings with Stakeholders

Stakeholder	Month (all in 2024)
College Leadership (Dean & Department Heads)	March
Undergraduate Curriculum Committee	March and November
College Advising Leaders	March
College Advising	March and October
Department Faculty	Monthly Faculty Meetings (March – December)
Peer Teaching Assistants	April
FYE 2.0 Advisory Board	April and December
College Admissions	October
College Programs	October and November
College Faculty	December

Meetings with the College Leadership and Advising

The early meetings with College leadership and advising involved providing an overview of the timeline and the initial plans to modularize the common FYE courses. Most of the questions they had pertained to logistics and scheduling. Our three-year plan involving a gradual transition to the modular format and the identification of common modules has helped answer some of the largest concerns. It is also clear that many are worried about scheduling for the first semester courses since this is typically done during summer orientation and advisors do not have a great deal of time to layout the options for incoming students. For the coming year, our 1 credit Design Course will be taken by all students and the 2 credit Engineering Applications course only has three options. Students will be recommended an option based on their major, and with three-fourths of the content similar between the choices, if a student is in the wrong section, this should not create too much of an issue.

Another question that came up was what to do if a student has a few extra free credits in the fall because they have tested out of a course typically required in the fall semester. Could they take 4 or 5 credits of FYE coursework in the fall and then 2 or 1 credits, respectively, in the spring? For year 2, we do not plan to allow this option, but this is a significant advantage of the modular format and something that will most likely be allowed beginning in year 3.

Other logistical questions centered around students having more final exams (one for the Design Course and one for Engineering Applications). For year two, we will still have a final exam for the Engineering Applications courses, but no final exam for the Engineering Design courses. Moving into year 3, we will require all exams to be given within the module (not during final exam week) and encourage instructors to use other assessments (mini-project or long homework) in lieu of a final exam.

Another valuable question was with regards to pre-requisites for modules. The primary question was what happens if a student fails the first module in a sequence and cannot take the second part during the same semester. This can be better explained by referring to the layout of Engineering Applications 1 in Table 2. If a student did not pass the Flow Diagrams or Python Module, they would not be able to take the Advanced Python module. For the Engineering Applications 1 course, this will not be an issue since they are all packaged into one course, but it could be a concern in future years once the full modular format is implemented. In general, our plan is to limit the pre-requisites and possibly use this as a motivation to better prepare our students for their second year and beyond. Currently in our first-year program, students could do poorly on the Python content, but do well with the design content/project, spatial thinking, and some of the other topics and ultimately end up with a passing grade in the course. This could create issues when they enter their future classes which rely on them being proficient in Python. Also, a student struggling with the Introduction to Python content is probably not ready to be doing advanced Python. With all this in mind, students would have to retake the Introduction to Python module and pass it before moving on to the Advanced Python module.

Meetings with College Programs, Curriculum Committee and Faculty

The first-year engineering courses taught out of our Department are taken by students in all Programs within the College and thus are considered a common college course. The College by-laws state that a change to such courses require approval by a majority of the Programs, followed by an approval by a majority of the Undergraduate Curriculum Committee and finally an approval by a majority of the College faculty. The meetings in Table 4 with the College Programs, Undergraduate Curriculum Committee and College faculty were all done to adhere to the by-laws and to get buy-in from the Programs and faculty.

The most informative and time-consuming meetings were with the Programs. The College is laid out such that there may be multiple degree granting Programs within a single department. For example, Mechanical Engineering, Mechanical Engineering Technology and Industrial Systems Engineering all reside within one department. This essentially leads to 15 Programs which, split into groups, leads to the seven departments within the College. Every Program has a Program Director, so initial meetings were setup with Program Directors to discuss the following items:

- The plan to modularize the courses including the three-year timeline;
- The 1-credit Design Courses to be offered each semester;
- What content from the current courses would they like to see carry over into the modular format;
- To what new topics would they be interested in exposing the first-year students; and
- Preferences for how many modules they would like to require and how many additional modules they would like to recommend, per semester.

The Program Directors then took this information to their Program faculty to get approval. A majority of the programs approved the change to modularization. The agreement was to have the two 1-credit Design Courses, 1 credit worth of modular content in the fall semester and 0.5 credits worth of modular content in the spring that Programs could require. Programs will also be allowed to recommend other modules but not require them. The general feedback indicated that most programs still wanted to see Python covered in-depth. This helps shape the layout of the Engineering Applications course shown in Table 3.

The remaining credit hours will be open for students to select modules of interest to them and their future careers. This ends up giving students the opportunity to choose 1.0 credits in the fall and 1.5 credits in the spring from among the modules offered. Also, the spring Design Course will become a choice module where students will be able to choose a project based on their interest (Robotics, 3D Printing, Product Development, etc). We anticipate this happening beyond year 3. However, some Programs have shown interest in developing some new projects for us, which could help us achieve this goal earlier.

Once a majority of the Programs approved the change to the modular format, the proposal was taken to the College Curriculum Committee. The College Curriculum Committee is composed of one representative from each department, a representative from our Co-Op office, a student government representative and the Assistant Dean of Academics. The meeting included a short 20-minute description of the plan and discussion. After the discussion, a vote was taken and the motion passed. The meeting was followed two weeks later by a College faculty meeting, where an even shorter description and discussion occurred due to the time constraints of the meeting. Once again, a motion was made and passed which ensured that the efforts to modularize the curriculum, and thus the NSF project, could continue.

Conclusion

This paper discussed the efforts at the University of Cincinnati, a large, midwestern, urban university to update their first-year engineering curriculum by providing students and programs more freedom to select content that will both better prepare students for their upper-division classes and specifically allow the students to pursue topics that are of interests to them. The paper discussed in detail the first year of the project, which involved implementing changes to the current courses to prepare for the change to the modular format along with getting buy-in from the administration, faculty, and staff within the college. The paper also discussed some outcomes from the changes implemented during this first year of the project and the plan for the second and third years of the project, with the goal of having a completely modularized first-year engineering course by the start of the third year (2026-2027). The outcomes from the first year have laid the foundation for successful transitioning into a partially modularized second year and a fully modularized third year.

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