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Work in Progress: Redesigning the First-Year Engineering and Computer Science Experience

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Work in Progress: Redesigning the First-Year Engineering and Computer Science Experience

Abstract

In this work-in-progress paper, we report on-going efforts to redesign the first-year experience for engineering and computer science students at the University of the Pacific. Pacific is a medium-sized, private student-centered university with Asian American and Native American Pacific Islander-Serving Institution (AANAPISI) and Hispanic-Serving Institution (HSI) status. The School of Engineering and Computer Science has a high proportion of first-generation and Pell-eligible students (approximately 40%).

The curricular redesign presented here is part of a broader effort to embed design throughout the curriculum and to develop an interdisciplinary experience that strengthens first-year students' sense of belonging and persistence in engineering and computer science. The desire to transform the first-year experience developed from a school-wide curriculum and pedagogy working group that engaged faculty from all departments. The working group reviewed and considered efforts to redesign first-year engineering experiences at colleges and universities across the country and identified skills that would better prepare first-year students for success in their future courses and careers. A major recommendation was the adoption of a new two-course sequence for first-year students. This sequence will replace the current one-unit introductory seminar course for first-year engineering and computer science students.

A backward design process — that began with student learning outcomes and produced content and assignments that would support these outcomes — was used by a subsequent summer working group to develop plans for the two-course sequence. This backward course design was facilitated using the TiLT (Transparency in Learning and Teaching) framework. The main goals for the two courses are to introduce design concepts and skills, foster a sense of belonging, and improve retention. The courses will incorporate active and project-based learning and emphasize design, real-world problem-solving, entrepreneurship, and interdisciplinary approaches. In addition, the courses will introduce college and career success skills, professional communication methods, and technical tools. The summer working group also recommended establishing a new program code, IDEA (Interdisciplinary Design and Entrepreneurship / Excellence in Action), to highlight the school's focus on interdisciplinary engineering and computer science.

We will start offering these courses during the 2024-2025 academic year. Efforts are underway to develop assessment tools to collect data on students' skill development, sense of belonging, and persistence in engineering and computer science majors.

Introduction

In this work-in-progress paper, we describe a backward design, faculty-led effort to redesign the first-year experience for engineering and computer science students at the University of the Pacific. The aims of this initiative are to incorporate design throughout the curriculum, promote students' sense of belonging, and increase retention.

Numerous studies have identified aspects that contribute to attrition in STEM education [1]. For instance, Tseng et al. studied differences between persisting and non-persisting engineering students at a suburban private university [2]. They found that curriculum overload and disinterest in engineering pre-requisite coursework were felt by both groups. However, the persisting students found the courses essential and worth the effort, while the non-persisting students disliked the lack of curricular flexibility and did not see the relevance of the pre-requisite courses [2].

Studies have also reported that students experience gaps between their expectations and experiences in their first year in engineering education [3]. Similarly, Meyer and Marx identify both individual and institutional factors that contribute to students' leaving engineering education [4] and, in a literature review, Geisinger and Raman identify six common factors: "classroom and academic climate, grades and conceptual understanding, self-efficacy and self-confidence, high school preparation, interest and career goals, and race and gender." [5]

There have been repeated calls to reimagine engineering education to better prepare students for the 21st century (e.g. [6]). Institutions across the country have redesigned their introductory course experiences in engineering in recent years. This includes, for instance, Oregon State University [7], James Madison University [8], Norwich University [9], Portland State University [10], Temple University [11], Clarkson University [12], and University of California, Irvine [13], among others. However, this is not a US-specific phenomenon, with institutions in other countries reporting similar efforts, such as the University of British Columbia [14] and Western Sydney University [15].

These efforts to redesign first-year engineering education are the result of various motivations. While some institutions worked to incorporate design into their first-year curriculum [13], [16], others aimed "to give students a better appreciation of what engineering is and what engineers do", including differences between engineering disciplines [14]. Finally, many efforts explicitly highlighted the goal to increase student retention [12], sometimes as part of broader university-wide efforts [11].

Often, such efforts also aimed to introduce new pedagogical approaches, such as active learning and project-based learning, into introductory courses [8]. Indeed, studies have shown that active learning increases student performance and "narrows the achievement gap for underrepresented students" in STEM education [17], [18]. A recent study by Nguyen et al. also found that "enrollment in the project-based introductory engineering course was positively associated with students' performance in some subsequent engineering courses and did not adversely affect students traditionally underrepresented in engineering." [19]

While the work presented here shares similar goals with previous efforts (for example, incorporation of design into the introductory engineering experience and aims to increase student retention), it differs in terms of our course design process and the students that we serve. In the following sections, we discuss the context at our institution, the process used to develop the two-course sequence, the resulting course design, and details on curricular adoption.

Institutional Context

The University of the Pacific is a medium-sized, private student-centered university with Asian American and Native American Pacific Islander-Serving Institution (AANAPISI) and Hispanic-Serving Institution (HSI) status.

Students entering the university have an unweighted average high school GPA of 3.6, which is low compared to peer institutions. Additionally, the CIRP Freshman Survey administered in 2015 showed that our incoming first-year students at the university have a lower academic self-concept (beliefs about their abilities and confidence in academic environments) than the comparison group [20]. In the same academic year, the follow-up Your First College Year (YFCY) survey indicated that these feelings of academic confidence reduce over the first year. Academic self-concept is even lower among senior level students at the university as measured by the College Senior Survey (CSS) conducted the same year. The CSS also indicated that sense of belonging in the senior year is lower than in the comparison group.

The undergraduate engineering and computer science programs are housed on our main campus in Stockton, CA. As of this academic year, to improve persistence, all first-year students are now required to live on campus. Students of all majors are distributed across the residence halls. Some students live in learning communities for students with similar profiles, such as first generation and honors students, but none of the learning communities are specifically intended for engineering and computer science majors.

Approximately 110 first year students enroll annually in the School of Engineering and Computer Science. Our school has a diverse undergraduate student population that includes 32% of students that have self-identified as Hispanic, Black/African American, or American Indian/Alaska. Nearly 40% of new first-year students in our school receive Pell grants.

Most of our first-year students declare their majors when they matriculate. Only a few students join as "Exploratory Engineering" majors who typically select a major by the start of their second year. All incoming undergraduate first-year students at the university take a common general education course seminar series emphasizing communication skills and critical thinking. Engineering and computer science first-year students also take a mix of introductory mathematics, science, and programming courses, depending on their declared major. Students are placed into mathematics courses based on prior experience or placement tests. A large percentage (~35-40%) of first-year engineering students at our university place into pre-calculus, which can delay their on-time graduation and may contribute to attrition. The 6-year graduation rate in engineering and computer science is currently at 70%. The work presented here aims to support students' self-efficacy and sense of belonging in order to increase the retention rate.

All engineering and computer science first-year students currently take a one-unit engineering and computer science seminar course in the fall semester that is offered in sections of 60 students. This course has an ambitious set of aims that includes an overview of the school's programs, professional and career opportunities, support services on campus (e.g. tutoring, career services, health and wellness), strategies for academic success in college, curricular and co-curricular planning, hands-on activities, and a team design project. For a one-unit course, the student time commitment can only be 3 hours per week including time in class, which allows only limited coverage of this wide range of topics and activities. The course sequence described in this paper is designed to replace this seminar course, expanding the unit load to be more aligned with the necessary time commitment to sufficiently cover the range of topics and to expand interdisciplinarity content. Additionally, smaller classes allow for a more student-centered experience.

Initial Impetus: Curriculum & Pedagogy Working Group

As part of a strategic planning and vision effort that began in 2022, the engineering and computer science dean established faculty and staff working groups to support the school's strategic vision. These working groups were tasked to address the following topics: outstanding student experience, industry and alumni partnerships, state of the art facilities, curriculum and pedagogy, and a supportive community. All faculty and staff in the school joined at least one of these groups and working group leaders were identified, usually consisting of one faculty and one staff member. The curriculum and pedagogy working group was comprised of faculty from each of the engineering and computer science majors. The composition and structure of the working groups ensured broad representation across the school and meant that efforts to promote the school's vision were led by faculty and staff.

The curriculum and pedagogy working group started its vision planning process with a set of brainstorming sessions to identify 1-, 3-, and 5-year goals. Faculty individually identified possible goals, which were then compiled. These goals were narrowed down by a democratic process and sorted into the 1-, 3-, and 5-year groupings. Some of the final goals included identification of new and existing signature learning opportunities and expanded support for innovation in engineering education within the school (e.g. through additional funding for conferences and workshops). The group also established several goals to incorporate more interdisciplinary design into the common curriculum. One goal that emerged from this process was the desire to evaluate the common curriculum and to reimagine the first-year experience.

As a first step in evaluating current curricula, the working group reviewed the degree requirements for each major within the school to identify common pathways. For most majors, the first two semesters share a common mathematics course, general education core sequence, and the introductory engineering seminar as shown in Table 1.

Table 1. Typical first-year curriculum (prior to redesign)

Fall Semester	**Spring Semester**
Calculus I [4 units]	Calculus II [4 units]
General Education – Problem Solving and Oral Communication [3 units]	General Education – Written Communication and Critical Thinking [4 units]
Science [4 units]	Science [4-5 units]
Major Specific Selective – Optional [3-4 units]	Major Specific Selective [3-4 units]
Introduction to Engineering Seminar [1 unit]	

The working group also reviewed introductory engineering experiences at other institutions (such as Bucknell University, Purdue University, Swarthmore, and Olin College of Engineering, etc.). Schools were selected for benchmarking based on ranking, reputation, and profile similarity. For many of these institutions, the first-year engineering experience includes a larger number of contact units, usually spread out over the first two semesters. The working group recognized the benefits of putting a greater emphasis on developing design and success skills during this critical phase. Drawing on the data collected on students' academic self-concept, the committee also agreed that interventions to increase students' sense of belonging, metacognition, and self-efficacy would be especially beneficial for our student population. The working group decided to develop a more comprehensive introductory experience that would preserve the college and career success skills from the previous one-credit seminar course while enhancing the design content to build self-efficacy. The plan to emphasize design content included complementary plans to incorporate skill-building in written and oral communication, teamwork, and problem-solving.

Initial results from all strategic working groups were presented at a school-wide sharing session where feedback was gathered and working group partnerships were established. The curriculum and pedagogy working group also presented the proposed first year revisions to a chairs' meeting and to the dean's advisory council to gather additional feedback. This feedback was incorporated with the revisions proposed by the curriculum and pedagogy working group and informed the dean's charge to a new summer working group to develop a framework for a two-course introductory engineering experience for all incoming students in the school (IDEA 10 and 20 in Table 2).

Table 2. Typical first-year curriculum (after redesign)

Fall Semester	**Spring Semester**
Calculus I [4 units]	Calculus II [4 units]
General Education – Problem Solving and Oral Communication [3 units]	General Education – Written Communication and Critical Thinking [4 units]
IDEA 10 [2 units]	***IDEA 20 [2 units]***
Science [4 units]	Science [4-5 units]
Major Specific Selective – Optional [3-4 units]	Major Specific Selective [3-4 units]

Collaborative Course Development: Summer Working Group

The summer working group included representatives from each department that were interested in the project goals and open to learning and applying equitable teaching and learning practices. Participants were given a stipend for their time. This faculty-led working group collaborated for two weeks over the summer with support from the university's Center for Teaching & Learning. The convener emphasized the importance of community building and began each day with an icebreaker activity. This mirrors the experience we hope students from the different disciplines will have in the new course sequence in getting to work with students from other majors. These community building efforts supported a collegial atmosphere that allowed decisions in the group to be made by consensus.

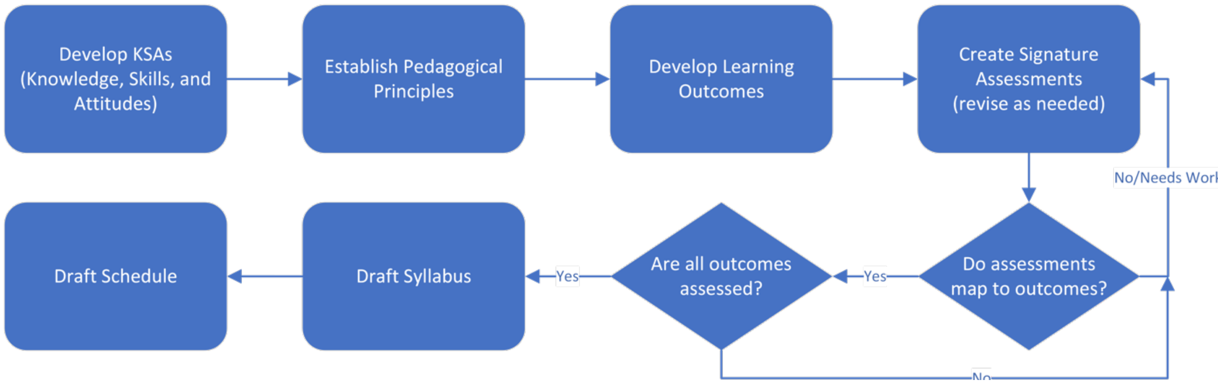

Figure 1. Backward design process flowchart

To develop the course content, the working group used a backward design process (see Figure 1). This process started by identifying essential knowledge, skills, and attitudes (KSAs) (Table 3). The KSAs were then used to develop student learning outcomes, which, in turn, were used to create key assessments and course assignments. In developing key assessments and course assignments, we discussed our course values and pedagogical principles. These included active learning, project-based learning, and smaller class sizes.

Table 3. Identified KSAs (knowledge, skills, and attitudes) for the course series

Knowledge	Skills	Attitudes
• Design Process • Curriculum • Resources • Learning Methods • Ethics and Values • Multidisciplinary Topics	• Teamwork • Communication • Time Management • Study Skills • Comfort with failure • Technical tools	• Appreciation of coding, programming • Societal impact/sustainability • Metacognition about strengths and weaknesses • "I can do this" • Acceptance of imperfection • Professionalism

The working group used the Transparency in Learning and Teaching (TiLT) framework to design the key assessments [21]. The TiLT framework emphasizes clarity in assignment prompts by providing a checklist of important items to consider (Table 4). These items include the assignment timeframe, due date, pre-requisite knowledge or tools, student learning outcomes, assignment tasks, and criteria for success [21]. Aside from improved assignment clarity, the framework clearly maps the student learning outcomes to each assessment prompt.

The last step in the process, which was informed by each of the previous steps, was developing the draft syllabi and course schedules. The resulting preliminary course framework was then presented to the school's faculty for further feedback.

Resulting Course Design

The summer working group developed the two-course (two credits each) series which incorporates aspects of active and project-based learning as well as interdisciplinary approaches in smaller class sections across two semesters. It also proposed a new program code, IDEA, for these courses. This course code will be applied to existing and future interdisciplinary design and entrepreneurship courses.

Table 4. Abbreviated transparent assignments checklist, adopted from the TiLT framework [21], [22]

Abbreviated Transparent Assignments Checklist	
Time	• Timeline • Due Date
Purpose	• Stated purpose of the assignment • Relevance to course, program, college, and/or professional outcomes • Content knowledge and skills that will be practiced or gained
Tasks	• Definition of activities students should perform • Steps, guidelines, and/or recommended sequence of efforts • Mistakes to be avoided
Criteria for Success	• Characteristics of a high-quality finished product • Checklist or rubric to guide progress • How the task/product will be graded and factor into overall grade for the course
Additional Considerations	• Is your assignment prompt visually organized and accessible? • How can you scaffold this assignment with smaller "stepping stones" assignments? • Can you analyze examples in class to distinguish between excellent and adequate work? • How will you encourage creativity so that examples are not seen as templates? • Will students have the opportunity to engage in peer review before final submission? • How will students reflect and comment on their completed, graded work after evaluation to identify what they did well and changes to their learning strategies that might improve future work?

The two courses, IDEA 10 and 20, are designed to introduce students to college success skills, human-centered design, problem-solving techniques, and technical tools. In the courses, students will also learn about different aspects of engineering and computer science. Another goal is for students to be introduced to our newly opened makerspace. The learning outcomes for both courses are shown in Table 5.

In light of students' other courses in their first year, the design of the courses is intended to have lab-like contact hours to facilitate projects and have students complete most work in-class. The courses also do not require a textbook (students will be provided with reading materials in class) and there is no lab fee.

Each course consists of three major team projects, which emphasize different aspects of the learning outcomes and the design process. In the first course, the projects are centered around data analysis, the design process, and service learning. The second course builds on the experiences in the previous course with an intermediate data analysis project, an assignment leveraging the new makerspace, and a larger bioelectrical project that combines aspects from both semesters and applies the concepts of the design process to a real-world need. Additionally, there are several smaller individual assignments on college success where students reflect on their learning process, methods, and mindset that are integrated with the first year advising program in the school.

Many of the projects involve teamwork. We plan to ensure that students from different disciplines are represented in each section and on each team. We also intend to follow best practices for team formation and will use the CATME tool for peer assessment throughout the courses [23].

Table 5. Learning outcomes for the course series

First Semester (IDEA 10)	Second Semester (IDEA 20)
• Apply basic computational and mathematical concepts for problem solving. • Describe how the courses in your curriculum plan integrate, develop an individualized path through the curriculum, at [the university], and toward your profession. • Identify and implement techniques for college and career success including time management, study skills, peer-to-peer learning, and professional habits. • Create and implement a process of continuous improvement for adaptive learning, including a dynamic understanding of individual strengths and opportunities for continuous growth. • Effectively and equitably engage in diverse, multidisciplinary teams individually and collectively to deliver an engineering or computer science solution. • Create and evaluate multiple feasible solutions to a real-life problem using an engineering design process that considers ethical and societal impacts. • Develop technical and scientific oral communication skills appropriate for different audiences.	• Explain the various disciplines [in the school] and evaluate how your selected major aligns with your skills, abilities, and interests. • Demonstrate professional habits of engineers and computer scientists. • Sustain a process of continuous improvement for adaptive learning, including a dynamic understanding of individual strengths and opportunities for continuous growth. • Effectively and equitably engage in diverse, multidisciplinary teams individually and collectively to deliver an engineering or computer science solution. • Create and evaluate multiple feasible solutions to real-life problems using an engineering design process that considers ethical and societal impacts. • Explain various models and tools used in computer science and engineering, evaluate the types of problems they are appropriate for, and use them to address real life problems. • Demonstrate technical and scientific oral and written communication skills appropriate for different audiences.

Course and Program Adoption

New courses must be approved by our engineering and computer science faculty council for inclusion in the academic catalog by the end of the fall semester. To be adopted into the curriculum, each program must submit curriculum change paperwork by the same deadline.

Prior to having faculty vote on the new two-course series, numerous rounds of feedback were conducted. Representatives of the summer working group presented the courses, learning outcomes, and example assignments at each department meeting, a program chairs meeting, and a faculty council meeting to seek feedback and comments. Most faculty supported the proposed changes. Some faculty recommended we start with a subset of programs or students that opt in; however, faculty resource limitations would not permit this option. A few faculty expressed concern about a change to the course because they supported the existing course's learning outcomes and activities. Their concerns were assuaged when it was made clear that the revised course would add to this foundation, preserving many of the components of the existing course. Another concern raised was regarding the possible impact of the curricular changes on our upcoming accreditation review. However, the assessment data shared in the ABET self-study would be collected prior to the first offering of these courses, making this the ideal time for implementing curricular changes.

Ultimately, the courses were approved at a faculty council meeting by a significant majority. Following approval, each program determined if they would adopt the courses, how the new courses would be integrated into their program curriculum, and then introduced their program changes for a vote by the faculty council. All but two programs voted to adopt both IDEA 10 and 20 and to replace the one-credit seminar course. One program adopted only IDEA 10 and replacement of the one-credit seminar course. The final program did not adopt either course but agreed that they would substitute IDEA 10 for the one-credit seminar course in the upcoming fall semester.

The two courses will be offered to incoming engineering and computer science students beginning in academic year 2024-2025. We expect to initially offer 5-6 sections of each course, as there are approximately 110 incoming undergraduate students in engineering and computer science. The summer working group agreed on the importance of involving a broad mix of full-time faculty in offering the two-course sequence. We are currently planning to involve nine faculty in another working group over the summer of 2024 to determine the day-to-day implementation of the courses. These faculty will have prior experience in active learning and project-based approaches and may also teach the two courses on rotation. Finally, in the time leading up to the summer, we are planning to send several faculty members to professional development programs (e.g. programs that focus on student-centered design or engineering design).

Assessment & Future Work

Throughout the initial offering of the two courses, we plan to collect data on students' sense of belonging, their teamwork experiences, and retention rates. To this end, baseline data has already been obtained for the two most recent first-year cohorts – collected at the end of the second semester – in order to gauge their sense of community. The data was collected with a voluntary survey using questions from the School Community Inventory (SCI) that measure feelings of social community and learning community [24]. We intend to conduct the SCI survey with the students in the redesigned first-year experience at the end of each semester to compare with results from the past cohorts.

Students will complete surveys that assess their motivation and confidence following each team project. CATME surveys conducted after each project will provide evaluation of teamworking skills over that time as well. This will allow us to study these factors longitudinally over the two semesters. Qualitative analysis of student reflections on their metacognitive and self-efficacy skills will be conducted. Additionally, interviews and focus groups will be conducted to capture narrative descriptions of the students' experience. Finally, academic measures including GPA and math grades will also be collected.

Conclusions

We have described the development of a new first-year engineering and computer science experience at the University of the Pacific. This two-semester course sequence is the result of an extended process that emerged from broader strategic goals within the school. Course development was led by a faculty working group that involved representatives from all programs. The working group intentionally met over the summer away from the pressures of the academic year. The committee, with support from the Center for Teaching and Learning, used a backward design process to design this course sequence and to develop assignments using the TiLT framework. The plan to assess the effectiveness of the program was also developed at this time. The proposed course sequence was then shared with faculty in the school for further feedback and refinement. The courses were ultimately adopted into curricula and a second summer working group comprised of faculty across the disciplines will develop the detailed day-to-day activities. The course sequence will be first offered in academic year 2024-25.

These courses aim to develop college and career success skills and covers human-centered design, problem-solving techniques, professional communication, and technical tools students will need throughout their studies. We hope that this experience will bolster students' academic self-concept and sense of belonging and thereby increase retention.

Beyond our own university, we also hope that faculty at other institutions, especially those with similar student populations (such as a large percentage of first-generation students) and motivations (such as an interest in retention and engaging students throughout their first year), may find this work useful in their own contexts. First, institutions planning to revise their first-year engineering experience may find the two-course structure across the entire first year relevant. Second, the approach presented here – a backward design process that adopts the TiLT framework – may also be applicable more broadly.

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