Exploring Civil and Environmental Engineering for First-Year Students

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Abstract

First-year undergraduate students who are required to select a major during the application process often times have a poor understanding of the topics and the breadth of possible career paths within their selected major. In addition, our civil and environmental engineering (CEE) curriculum did not provide meaningful engagement for the students until the end of their second year at the institute. Therefore, it was not surprising that the retention of students within the major was as low as 50%. To improve student retention by helping students learn more about the CEE field and build their professional identity as soon as they enter the major, a new course was developed for first-year students within civil and environmental engineering. This course has been taught in the fall semester commencing in 2019. It is designed to be highly interactive meeting one hour a week in standard lecture format and two hours a week in smaller studio sessions. The course is organized into four modules with each covering one of the major cross-cutting areas within the program and with each module consisting of Learn, Do, and Reflect components. The students work in different teams for each module completing a short team project related to the module topic. They also complete a self-reflection exercise at the end of each module as well as a culminating reflection at the end of the course. The course includes professional skills development in engineering communication as well as teamwork with academic professionals working with the students during several sessions. The course also introduces story-driven learning allowing the students to begin to build their professional identity and to see how they fit within the major. Assessment of the effectiveness of the course includes survey data collected throughout each semester. In addition, because the class was originally optional, student retention data compared between the cohort taking the class versus those who have not taken the class has shown the benefit of the course. Furthermore, a culture survey has shown the benefit that the course has for the students to develop a sense of belonging to the school and their major early in their academic journey.

Introduction

Student retention has been an ongoing challenge within higher education for many years, particularly within STEM fields such as engineering [1]. For programs in which first-year undergraduate students are required to select a specific major during the application process they oftentimes have a poor understanding of the topics and the breadth of possible career paths within their selected major and may make uninformed decisions to change prior to any meaningful engagement with their original major. First-year engineering courses can play an important role in shaping students initial academic and social experiences, thereby helping with student retention (e.g. [2,3]). They can also help students better understand the career path they have selected so they can determine if they are indeed within the best major for their personal career goals (e.g. [4]).

Many programs have been introducing first-year engineering courses as a means for familiarizing students with their programs and helping them begin their academic journey. Recent studies have emphasized the importance of designing these courses to foster engagement using problem-solving and real-world applications. For example, problem-based learning (PBL) is

useful in first-year engineering courses by helping students develop critical thinking and problem-solving skills while making the learning process more engaging [5]. PBL in this context has been shown to improve student's understanding of how their engineering education fits within their worldview. Similarly, in another study [6], integrating hands-on activities with practical applications enhances learning and helps students build higher levels of self-efficacy. This helps student's sense of belonging to the profession, increasing their commitment to staying in the engineering program.

Student retention is highly related to the level of engagement, both social and academic. Helping students obtain a sense of belonging within their academic environment is undoubtedly beneficial in improving retention. Research has shown that building a strong community within the first-year engineering population was associated with higher retention rates [7] accomplished through participation in an Engineering Learning Community. Another study [8] provides a comprehensive review of literature from 2018 to 2023 and highlights that inclusive teaching strategies—such as active learning, culturally responsive pedagogy, and universal design—are associated with improved retention rates in engineering programs.

Another factor in student retention is their psychological well-being, particularly during the high-stress first year of college. Ensuring mental health interventions are available for students, including mindfulness and support services, helps to improve student outcomes and reduce dropout risks [9]. The emotional challenges from the high level of stress due to the rigorous coursework in the early engineering curriculum can be mitigated when students feel supported. Another study suggests that helping students obtain a growth mindset can also help with their resilience to view challenges and setbacks as opportunities for growth are more likely to persevere [10].

In 2018, the CEE program identified that approximately 50% of the students who initially enrolled in the major as first semester freshman completed their degrees within CEE. The students who left the program switched their majors to other degree programs at the institute during their first or second year. We felt a major driving factor of this attrition was because the curriculum did not provide meaningful engagement within CEE for the students until the end of their second. Therefore, we felt it was imperative to create an early engagement class for incoming first-year students to help them engage with the CEE program and profession early on in their college career. This paper describes the implementation of a new first-year course for CEE students. The research question we are looking to answer is "can an engaging first-year course that helps students develop a sense of belonging within the program and profession and learn important professional skills have a positive impact on student retention?"

Course description

Exploring Civil and Environmental Engineering is an introductory course for first-year engineering students within the school of civil and environmental engineering (CEE). The purpose of the course is to help students learn more about the CEE field and begin developing their professional identity. This course has the following specific learning objectives related to developing a professional identity:

1) We aim for this class to help you understand what civil and environmental engineers do and develop a personal connection to CEE practice;
2) We will ask you to start learning the language and practicing the basic tools of CEE, including problem scoping, scenario analysis, common calculations, and communicating your thought process and experiences in writing;
3) We aim for you to become familiar with the types of infrastructure, design considerations, ethical considerations, and social, environmental, and cost constraints commonly encountered in CEE and learn how CEE engineers create value for society through their work;
4) We aim for you to develop the ability to think critically about CEE-style problems, drawing on experience you will gain by actively thinking through and observing challenges;
5) We sim got this class to build your curiosity for the profession, such that you will know where to go for more information and will have a better sense of the kinds of classes you might be interested in, the kinds of jobs you will be able to do with a CEE degree, and the kinds of problems you are interested in working on.

In addition to the learning objectives related to professional identity there are numerous objectives for developing professional skills. These include the following:

1) Teamwork: Students will be introduced to basic teamwork concepts;
2) Communications: Students will be introduced to basic engineering communication skills related to written technical reports and oral presentations;
3) Story-driven learning: Students learn how to tell compelling stories, articulate how they ended up in CEE, and visualize where they see themselves in the future;
4) Sense of belonging: Students develop a sense of belonging within both the school and profession.

To achieve these learning objectives, the course is designed to be highly interactive for the students. The class meets one hour a week in a standard lecture format with approximately 60 students, and two hours a week in smaller studio sessions with 30 students each. The two-credit semester-long course is organized into four modules with each module consisting of Learn, Do, and Reflect components. Each module covers one of the four major cross-cutting research areas that have been adopted within the school: Smart Cities, Resilient Infrastructure, Healthy Communities, and Sustainable Systems.

The modules are structured as follows: during the first week of the “Learn” portion of the module the topic is introduced during the lecture portion of the class. During the studio session in the first week, additional material is introduced and students participate in various activities to help them learn more about some of the concepts and tools used within the discipline. The students have to complete a homework assignment with a variety of problems and open-ended questions related to the module topic during the first week. During the second week of the module, a faculty

guest speaker with background related to the module topic presents in the lecture. During the second week studio session, students commence working on a one-week long group project that is designed to include open-ended questions as a problem-based-learning project relevant to the module topic. During the third week of the module, an outside guest speaker with background relevant to the module topic presents their personal professional journey. The final studio session of the module is either used for student project presentations or a story-driven learning activity. The students also complete a self-reflection exercise at the end of each module as well as a culminating reflection at the end of the course instead of a final exam.

Teamwork is an integral part of the Exploring CEE course. Each of the four modules within the course had team-based projects in which random teams comprised of four students each were created at the start of each "do" phase. New teams were created for each module, helping the students to engage with more classmates during the semester. Two of the projects culminated with 10-minute presentations and the other two with an 8-page technical report. Before the first group project, a faculty member specializing in team development worked with the students in a studio session about "Creating an Authentic and Safe Team Culture" for developing more effective teaming strategies.

Engineering communication is embedded throughout our curriculum in multiple courses. The basics ideas for technical report writing and oral presentations are first introduced during this class. The students have a short session led by our engineering communications academic professional and are provided with best practices for engineering writing and oral presentations. The group projects culminate in either a submitted written report or an oral presentation. As this is the introduction of engineering communication within the program, detailed guidance is provided on the requirements for each of the project products.

There were multiple story-telling activities throughout the course. During the studio session in the first week before the modules begin, the instructors and TA shared their personal stories about how they ended up in college and started their personal career path. The students were then asked to share their personal stories within small groups about how they ended up in this program. The discussion also focused on the elements of effective story-telling: containing a transformation, immersing the listener in the environment, including sticky details, and containing some sort of emotion component as well as the benefit for story-telling within their future career paths.

At the end of the first module, approximately a month into the semester, a studio session was fully dedicated to story-telling. The session included activities in which students go "back in time" to talk about what they loved to do as children, including creating drawings of what an ideal invention or gift to their 10-year-old self would be. After discussing this in small groups and with the class, the students reflected on what the child (young them) would think about where they were then, e.g., what would they love about you studying to be an engineer at this university? Then progressing to 10 years into the future, the students had to imagine a potential future for themselves. They had to pick a scenario and describe where they were and what they were doing. This again was done in small groups and then with the rest of the class. To help them see that there

were many options and that their path was wide-open, they had to completely reset and tell a brand-new vision about another possible future.

During another studio session near the end of the semester, an academic professional worked with the students on how to handle failure. The focus was on various definitions of "success" and developing a growth mindset rather than a fixed mindset. Different tools and strategies for coping with setbacks and failures were discussed. The purpose of this session was to help the students begin to understand the benefit of approaching challenges and setbacks with a growth rather than a fixed mindset to help their psychological well-being.

All the previous mentioned assignments and activities helped encourage the students develop their sense of belonging within the CEE profession and develop professional skills. To facilitate development of their sense of belonging within the school itself and to help them learn more about the resources available, we included a scavenger hunt assignment. This was assigned during three different "cycles" within the semester in which they were required complete three of the five activities assigned for that cycle. These activities were as simple as finding all the CEE related academic buildings and taking a selfie in front of them, reviewing the academic advising resources available and filling out their personal curriculum flowchart, or participating in our lunch-with-a-prof program in which the school sponsors students and faculty members to engage over lunch various topics professional and personal, e.g., career choice, graduate school, study abroad, family and others. Each cycle contained a new set of activities from which they were required to complete at least three.

Results

This course has been taught as an optional course for first-year students since Fall 2019. The enrollment each semester is summarized in Table 1 below. The student enrollment increased the first three years it was offered until the desired steady state of approximately 60 students was obtained. During these offerings, this was an optional course that did not count towards their degree. It is also important to note that students who already had questions or concerns about CEE as a major were encouraged to take the class and preferentially enrolled in this course.

Many of the learning objectives were directly assessed for this course. For example, written communication was assessed at the group level based on the project reports from two of the modules. Oral communication skills were assessed at the individual level during the presentations for the other two modules. Teamwork was assessed based on the success and functionality of teams during each module. However, because the primary focus of this paper is on the impact of this course on student retention through the development of a sense of belonging, we discuss the data related to retention and sense of belonging throughout the remainder of this section.

The direct metric is the student retention rate within CEE for students who took the course. Historically, approximately 50% of the students who matriculated as first-year students in CEE ended up changing their major before graduation. Within our program, most students who change their major out of CEE do so during their first year or early in the second year. The number of students leaving our program is much lower in subsequent years following a number of

interventions to improve retention. Therefore, the data in Table 1 will not be changing much, even for the most recent cohort listed from Fall 2023.

The number of students changing their major out of CEE for all five years is significantly below the original level of 50%. The most recent cohort from Fall 2023 has the lowest attrition rate of only 17%. For comparisons, for both the Fall 2019 and 2020 cohorts of students who did not take this course, 43% of the students changed out of CEE, substantially higher than the rate of students who enrolled in the course.

The course has undergone some evolution in structure during the five years it has been offered. The first year it was offered in 2019, the class was implemented as a 3-credit course meeting once a week for three hours. While the feedback from the students about the course was quite positive, one common critical comment was that meeting once a week for three hours was challenging and a major drawback for the students. Subsequently in 2020, while due to COVID-19 the course was offered virtually, it was modified to meet twice a week for 75 minutes. In 2021, the class was still a 3-credit course meeting in-person twice a week. Finally, in 2022 and 2023 the class was switched to the current 2-credit model, meeting once a week for the lecture and once a week for the 2-hour studio session. These changes were primarily to the course format and not to the content. Although retention was improved for all the years, the retention data after the format change is even better. Also, the new format is more scalable for a larger cohort of students when Exploring CEE becomes a required class.

An indirect measure of the impact of this course on student retention is from their personal reflections at the end of each module where students articulated the impact of the course and the associated activities. The students also completed a final reflection at the end of the semester summarizing their experience in the class. Many of the students articulated the benefit the course had in helping them confirm they were in the correct major. Many of the students who changed their major described their personal reasons for the change, making it clear that they were making an educated decision based on a clear understanding of CEE careers. We feel this is a significant improvement compared to students who changed out of CEE before ever experiencing any of the major courses or having any meaningful interactions within the school.

Table 1: Number and Percentages of Students Leaving CEE after taking Exploring Civil and Environmental Engineering

Year	Number of Students in Exploring CEE	Number of Students Leaving CEE	Percentage of Students Leaving CEE
2019	24	6	25%
2020	48	14	29%
2021	64	22	34%
2022	60	15	25%
2023	59	10	17%

To help illustrate the perception the students have of the impact of this class, here are a number of quotes from students in their reflections on the course:

- "This course has expanded my view of what CEE actually is. Before taking this class, I was struggling to describe my major to my parents. After, I can't stop talking about what I am excited about because of this class."
- "Before we started this section, I was really having issues with imposter syndrome, not just at this school, but within my major . . . we were assigned the project to design a sustainable building on campus, a lightbulb went off in my head."
- "I can look back on this assignment and remind myself that there are things in this major that excite me, and it is worth the long haul to be able to make a positive impact on the planet."

A survey instrument was introduced in 2023 as an indirect assessment in which students were asked about their experience in the class. One of the questions targeted their sense of belonging by asking: "How much did this course help you connect with your classmates and feel part of the school's community?" and gave options for none, low level, moderate level, and high level. All 59 students responded to the survey. Figure 1 shows the responses. Nearly 95% of the students felt that the course had either a moderate or high level impact on their sense of belonging.

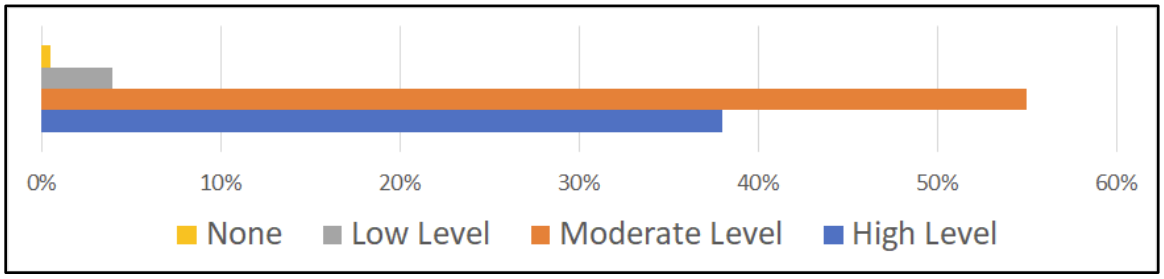

Figure 1: Percentage of students responding to the question "How much did this course help you connect with your classmates and feel part of the school's community?" from the 2023 cohort.

As part of a department RED (Revolutionizing Engineering Departments) grant from the National Science Foundation, an initial culture survey was undertaken in 2021/2022 with a set of closed and open-ended questions. As part of this survey, students were asked questions that allowed an assessment of their sense of belong and various factors that impact this such as their perception of culture, their network size, and their understanding of the CEE job market. Despite the small number of students who had taken Exploring CEE at this point (2019-2021 classes), there was a high enough response rate to distinguish between the different cohorts. There were responses from 39 students who took Exploring CEE and 71 students who did not (either opted to not take it or matriculated prior to the course being developed).

To measure community building within the program, students were asked to document their network size. Students who had taken Exploring CEE showed a statistically significant larger network size of 3.39 versus 2.30. The survey also quantified that the cohort from the class had a statistically higher perception of the culture of the school, a positive indicator of developing a sense of belong. In addition, specifically for freshman and sophomores (21 students took the class and 21 students did not take the class), students who had taken Exploring CEE showed a statistically significant higher level of understanding of the potential CEE job market.

Understanding the job market provides students a better vision of how they can fit within the major, perhaps leading to fewer students prematurely leaving the major. However, by the time students were at the junior/senior level, both cohorts showed a statistically similar understanding of the potential job market. This indicates that the program does a good job of helping students understand their career path later in the curriculum. Therefore, helping students understand the job market earlier in the curriculum through this new course is a benefit for retention during the early years when most students have changed their majors within our program.

Conclusion

The course Exploring Civil and Environmental Engineering was developed with the primary purpose to help improve student retention within the CEE major. The hypothesis was that creating a highly engaging course that develops the student's sense of belonging within the profession as well as the program would help improve retention. The course also introduced a number of professions skills such as communication and teamwork and used story-driven learning to help with the personal reflection and professional identity development. Activities within the course were designed to help the students form communities and learn about developing a growth mindset.

The course has been shown to be successful in introducing first-semester students to the CEE profession and program. The course was designed to facilitate engagement with the students through problem-based learning activities, increase their social engagement within the program, and benefit their psychological well-being. The survey data has shown that students in the course have bigger networks, a good perception of the school culture which as translated into a higher sense of belonging than students not enrolled in the course. We have hypothesized that this improved the retention of students within the CEE program.

While the pilot version of the course was focused solely on first semester freshman, moving forward, the course is now targeting all students at the beginning of their path through the CEE curriculum. Because the focus of the course is about being introduced to the profession and the program within CEE as opposed to an introduction to college life, it will be useful for all students embarking on this degree path within CEE regardless of their starting point (new freshman, transfer, or change of major).

Future Work

Beginning in Fall 2024, the CEE curriculum has been revised such that all new students are required to take this course as part of their degree requirements. In Fall 2024, 133 students enrolled in this class, which required the formation of four separate studio sessions. While the students in the class were primarily first-semester freshman, for the first time a number of transfer students and change of major students enrolled as well. The course was offered twice in the 2024/25 academic year with 52 students enrolled in the spring semester. More than half of these students are transfer and change of major students, including one student who expressed an interest in the learning more about the major prior to changing majors.

New assessments are being developed to more rigorously assess the benefits of this course. A new survey instrument is being developed for the indirect assessment that will track the students' perceptions of their sense of belonging and how these evolve over their time within the program. We are also developing a new protocol for directly assessing the learning objectives through evaluation of several of the class artifacts including the group projects and individual reflections. The intention is to develop a dataset that tracks student progress to evaluate the effectiveness of this course and other courses throughout the curriculum for helping students enhance their sense of belonging and the corresponding retention within the CEE program.

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