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Development of a Project-Based Civil & Environmental Introductory Course

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Work in Progress: Development of a Project-Based Civil & Environmental Introductory Course

Introduction

Teaching "soft" skills to engineering students presents a unique set of challenges compared to technical skills. Topics like technical writing and oral presentation are not commonly perceived by students to be in the domain of engineering while most practicing engineers would disagree [1]. Communication skills are just one example of a range of professional skills outside of discipline-specific skills that can aid new engineering graduates. Our civil and environmental engineering (CEE) curriculum committee developed communities of practice to oversee the implementation of curricular changes that develop and reinforce a range of non-technical skills to better equip our graduates for the discipline.

The end result will be that each skill is taught and reinforced at each level of the curriculum (Figure 1). This change been motivated by the changing expectations of faculty, alumni, and the profession at large. Faculty need graduate students with stronger communication and computational skills. Alumni desire clearer communication, a greater understanding of the profession, and more system-level design experience. In addition, alumni have indicated a desire for entrepreneurial thinking as engineering becomes more cross-disciplinary. Finally, governing, professional organizations like the Accreditation Board for Engineering and the American Society of Civil Engineers have increased the emphasis on computing and communication skills for the undergraduate education [1].

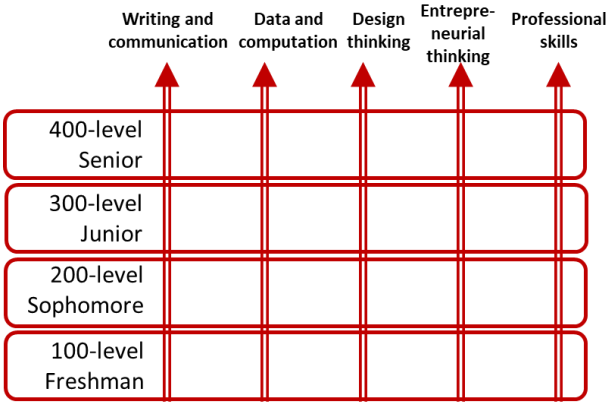

Figure 1. Areas for department communities of practice

While the curriculum offered several courses at the higher levels where these skills could be implemented, the number of courses at the lower levels were limited. At the first-year level, the only course in the department was a one-credit introductory seminar. In this course, students learned about the curriculum, an overview of the civil engineering sub-disciplines, and ongoing

research in the department. This introductory course was targeted for expansion to introduce a wider range of skills while maintaining the role of orienting new students to the department.

Introductory engineering courses are widely viewed as the gateway to an engineering program. Often, it is the first time for new students to interact with department faculty, learn more about the curriculum, and experience the profession. The implementation of these courses varies widely from program to program. Some courses span many engineering disciplines where others will focus on a single department [2–5]. Likewise, the pedagogy can vary from projects-based principles where design is emphasized to others that rely on traditional seminars and rote memorization [6–9]. While there is variability in execution, many introductory courses aim to provide some foundational knowledge of the program and develop skills that will aid students in the future of the program. Programs that have implemented best-practices into their introductory courses have reported better outcomes for the students while also improving retention [2–4,7,10].

With this knowledge, the introductory course was overhauled to both establish the expanded skillset from the communities of practice (Figure 1) and introduce students to the department and civil engineering profession. The format was changed from a seminar with individual reflection assignments to project-based learning with a high degree of teamwork. The time commitment and credit given were modified from 1 hour to 4 hours per week to allow for the additional work on a semester project. The increase in credit was allowed due to curricular changes in other parts of the program.

Due to the size of enrollment and scale of changes, the course has been in development since 2015, and changes were made based on best-practices for problem-based learning and feedback from the students. Fall 2020 was the first offering at roughly half capacity (roughly 90 students) and Fall 2021 was offered at full capacity (roughly 190 students). This paper discusses our process and the current progress in overhauling this introductory course in light of the larger, department-wide curricular updates. Data collection, at this point, is used for internal purposes only.

Redefining Objectives

Early in the process of redeveloping the introductory course, the lead faculty identified several key objectives to serve as the foundation for the course (Table 1). The objectives served to connect the course with the department’s communities of practice to guide development using established best practices. The presented objectives have refined throughout the course development process.

Table 1. Introductory course objectives and corresponding department community of practice

	By the completion of the course, students should be able to:	**Department community of practice**
1	Describe the areas of study in the CEE department	Professional skills
2	Describe potential career paths for CEE graduates	Professional skills and Entrepreneurial thinking
3	Manage assignments and meet deadlines	Professional skills
4	Process and present data	Data and computation
5	Communicate through written and oral presentations	Writing and communication
6	Work as a team to complete a feasibility study	Professional skills and Design thinking

Objective 1

A critical objective for the course is to orient the students to the department and introduce the various areas of civil engineering, which was the primary objective of the prior introductory course. Civil and environmental engineering is a broad discipline with distinct sub-disciplines. Due to this breadth, our program allows students to take a broad or narrow set of courses in the sub-disciplines. In the redeveloped course, students receive mentoring and guidance about the breadth of the discipline through a series of interactions with faculty, alumni, and senior-level students as the enrolled students complete their semester projects.

Objective 2

To aid with Objective 1, we introduce students to a range of alumni with varied career paths. Many students are only aware of the typical, new-design careers, and we aim to provide them with a broader perspective of potential careers. The career paths include traditional and non-traditional routes [11]. Engineering design, forensics, entrepreneurship, management, and policy-making are among the potential paths commonly presented. With this information, students can make better-informed decisions about coursework and internships.

Objective 3

Undergraduate students need to develop time-management skills as quickly as possible [12]. CEE students need to develop team- and project-management skills. Students are taught fundamental skills for organizing and managing large, multi-faceted project. Students practice these skills as they propose a study plan for the semester project, track and report progress, and revise the schedule as the semester progresses. In the redeveloped course, students receive mentoring and feedback about their schedule and progress on their semester project through a series of interactions with faculty and upper-level students.

Objective 4

Data presentation skills and fundamental programming skills are critical to engineers. Students need to work with data to process and present it effectively[13]. Spreadsheet calculations and display tools provide a basic skillset and introduce fundamental programming concepts which will prepare them for more sophisticated programing in subsequent coursework.

Objective 5

Technical communication skills, like many other skills, are developed through practice. Students are introduced to the key aspects of technical writing and given several opportunities to practice, receive feedback, revise, and reflect [14,15]. They also learn about best-practices for oral presentations and have opportunities to practice presenting as well. In the redeveloped course, students receive mentoring and feedback about their written semester project reports and oral presentation through a series of interactions with faculty and upper-level students.

Objective 6,

Teamwork is commonplace in the engineering profession and allow students to develop interpersonal skills. Students receive instruction about functioning on a team and form teams to accomplish unified goals [16,17]. The concept and steps of design are introduced through the semester project. Students select and complete the first component of a project, a feasibility study.

Implementation

The redesigned course was first piloted in 2015 as a junior-level elective with full implementation as an introductory course in 2020. In the initial pilots, the format and assignments were developed and modified each year to better meet the course objectives. By offering it as an elective, the course size was limited to 30 students which allowed for a higher level of interaction by the two faculty instructors. Frequent feedback during the pilots allowed for constant modification. In Fall 2020, the course was released as the intended introductory course, and enrollment grew to just under 100 students. In Fall 2021, the course reached the full-expected enrollment of just under 200 students.

Course Format

In the development of this course, the instructors used a project-based learning framework. The overarching goal for the students is to develop a feasibility study of some project around campus. Various modules consisting of seminars, field trips, and advising support the project which culminates in a final report reviewed by the instructors and an oral presentation in front of a panel of faculty and alumni judges. The key aspects are described herein and are mapped to relevant course objectives in Table 2.

Table 2. Mapping of course elements to course objectives

	By the completion of the course, students should be able to:	***Case Studies***	***Guest speakers***	***Field Trips***	***Sections of a Report***	***Computation Skill Building***	***Semester Project***
1	Describe the areas of study in the CEE department	X		X			X
2	Describe potential career paths for CEE graduates	X	X				
3	Manage assignments and meet deadlines	X		X	X	X	X
4	Process and present data					X	X
5	Communicate through written and oral presentations				X		X
6	Work as a team to complete a feasibility study						X

Case Studies

In the previous seminar-based course, the faculty would lecture about key aspects of their sub-discipline, the curriculum requirements, the faculty in the area, and an overview of ongoing research. In the re-design, we wanted to preserve the content of these seminars but work towards an interactive presentation. We also continue to bring in faculty from across the department to present the information. Instead of a factual presentation, a case-study is presented to provide contextual background on the sub-discipline. The case studies include either a past project or current research from the faculty.

In the lead up to the case studies, students are assigned technical background reading which is paired with a low-stakes assessment like a short reflection essay, short-answer responses, or a multiple choice quiz. In the subsequent lecture, the presenter will ask quantitative and qualitative questions based on the reading and lecture content where students must respond with a remote-response system (iClicker). The in-lecture responses are a formative assessment for the presenter, and responses are only recorded for attendance purposes. Following the lecture, students are assigned another formative assessment to reflect on the lecture content.

An example of a case study is a presentation on the development of the creek that runs through campus. All in-person students would have crossed this waterway on their way to class. Students read about the hydrologic history of the region and problems from regular flooding. The lecture highlights the various designs that were considered to control the flooding, the final design, and some of the economic and societal impacts. As one of the first case studies, it serves to present

the technical information about the sub-discipline, it illustrates interactions among the civil and environmental engineering sub-disciplines, and also connects the new students to a local engineering project on campus.

Guest Speakers

Throughout the course, alumni are invited to give presentations about their career or a project that was unique or interesting. The primary motivation for these speakers is to connect students with the profession. We encourage speakers to include information about their background, internships, licensing, teamwork, and career path. Students will see that career paths are rarely direct, failures happen, and they need to be lifelong learners.

The alumni are scheduled to include a range of sub-disciplines, educational backgrounds, and career stages. We also include a speaker who is not in a traditional CEE position (e.g. the CTO of a software company). Students are encouraged to ask questions during the lecture, and most speakers will converse with students after their presentation concludes. The only assessment for this activity is a reflective essay the students complete after the lecture.

Field trips

One of the most positive aspects of CEE is the ability to see our projects. With certain case studies, we are able to pair the case study with a field trip to the actual or representative site. These hands-on experiences reinforce the technical content, while further connecting the students to the campus, surrounding community, and the CEE profession. Currently, the trips include tours of the campus creek, a renewable energy campus facility, a wastewater treatment plant, and an active construction site. In each of these cases, a case study is presented prior to the trip, and students are asked for a reflection essay about the trip.

Sections of a report

Technical communication is the cornerstone of this course which is developed in the Sections of a Report module (SOAR). Many of the daily assignments require some amount of writing and the largest component of their grade is based on a written and oral report. To support communication development, we adopted strategies where the process of writing is emphasized, not simply the final product [15]. By focusing on the process, students are encouraged to treat writing as a cycle with revisions and reorganization. For the oral presentation, best-practices are given and students practice presenting to their peers and mentors before the final presentation with judges.

This class module is spread over multiple weeks and reflects the project reporting structure. Each lesson presents a single section of the report (introduction, scope, results etc.). Students watch a short video (~15 minutes) prior to attending class that covers the basic content of each section. The videos also serve as a reference when they are generating their final report later in the semester. The class period is dedicated to activities where students will revise writing samples using the think-pair-share format. After strengths and weaknesses are identified, students will practice writing and revising writing in small groups. Instructors facilitate large group discussions about the writing samples, and circulate during the individual and group writing/revising sessions. At the completion of the lesson, student submit their writing for

feedback from the instructor team. In these assignments, assessment is formative to encourage the “writing is a process” mindset.

Additional lessons in this module are professional correspondence and oral presentations. In both cases, best practices and context are provided. Students complete similar assignments as described in the technical writing section above. The topics are covered at a point in the semester when students are gathering data for their projects and may need to reach out to administrators in the university. Students also present their project ideas to mentors and peers for feedback during the development phase.

Computation skill building

The computation skill building is intended to bring all students to a basic level of competency with processing and presenting data using a spreadsheet. Through the lesson series, students learn to import data, use built-in functions to perform calculations with the data, and generate and format different types of plots. Students are given short instructional videos that explain the different spreadsheet functions and steps needed to complete the data analysis.

During the class period, students work individually to complete an assignment that utilizes the skills presented. The faculty instructors and teaching assistants circulate throughout the class to answer questions and troubleshoot problems. By the completion of the period students generate a plot of the assigned data following guidelines in the assignment. The assignment is a summative assessment focusing on both completion and accuracy.

Semester Project

The semester project is the focal point for this redesigned course and all aforementioned aspects of the course support the project. The project was formatted using best practices to engage first year engineering students [6,9,18–20]. The project is an open-ended project where students have autonomy to create the project and choose their teammates. Their objective is to complete a feasibility study for a project they formulate on or around campus. Early in the semester students work individually to identify potential project ideas and pitch these ideas to their classmates in *Journal Submissions.* ~~Students begin this project~~ Several weeks into the semester project teams are finalized and teams then spend the rest of the semester researching and building a series of three *Milestone* reports. At the completion of the project, students present their final report as a presentation to a panel of judges comprised of faculty, alumni, local professional engineers, and university administration.

Journal Submissions

The journal is the first phase of the project and consists of project ideation. This is a individual exercise with students exploring campus to generate ideas about engineering projects that hold their interest. When this phase is launched, students have already had several case studies, field trips, guest speakers, and SOAR lessons. As a result, students have an idea about the need for different types of engineering projects and can begin to articulate the work of a CEE. Students are encouraged to explore campus to think about potential CEE-related projects.

There are three deliverables in this phase, and each deliverable follows a similar format: submit a list of projects, consult with peers and mentors, and submit a refined list. The grading is assigned

based on completion to encourage students to be creative without worrying about having the "right" idea. With each deliverable, the list of ideas is pared down until one remains. In addition, students are continually working with their peers to refine their ideas and identify colleagues with similar interests. At the third and final round, final ideas are approved by faculty and recorded into a master list and students finalize their teammates. While faculty have the final approval of ideas, the iterative process allows ideas to be modified at multiple points to ensure the scope and level of technical understanding is appropriate. At the completion of this phase, each project group is assigned a faculty mentor and a teaching assistant mentor.

Milestones

In the second phase, three milestone reports are developed. Each report consists of and follows the corresponding SOAR writing lessons. The first milestone report serves as the proposal, the second is an interim report, and the final report summarizes their work on the feasibility study. Between the submissions, groups are generating content and consulting with mentors. In the first milestone, background, objectives, and planning are emphasized. The second emphasizes initial data collection and presentation. The third is the final report summarizing all of their work and drawing a definitive conclusion about the project's feasibility. Leading up to each submission, students submit drafts that are peer-reviewed and discussed before the final drafts are submitted. With the second and third milestones, students are revision and building onto the previous submissions. While each milestone is assessed, the emphasis remains on continual improvement to reinforce the "writing as a process" mentality.

Since this project is heavily dependent on teamwork, each student evaluates their contribution and the contribution of their teammates. Their peer scores are tabulated against their team scores. Students who have significantly lower scores are contacted by the faculty instructors to ascertain the cause of the low score. At the discretion of the faculty the milestone scores may be modified based on these peer evaluations. This early intervention allows the faculty to identify low-functioning teams, and help them to make strides towards improvement.

Public Presentation

At the end of the semester, students present their final projects to a panel of judges drawn from a pool of alumni, faculty, local professional engineers, and university administrators. From the student perspective, the presentations garner additional feedback that the group may include in the final submission, and it allows some projects to connect with stakeholders who aid in further development. Multiple university projects have grown out of the feasibility studies from this course. From the department's perspective, the event further strengthens the alumni networking and connects the students with local engineering professionals and with the faculty (many who presented case studies) ~~with students~~. The judges assess presentation quality and content and the top presentations receive extra credit.

Instructional team

Faculty

With the current enrollment of roughly 200 students, three faculty are involved as instructors. Their responsibilities include course management, content delivery, project mentoring, office hours, and assigning final grades. Each faculty instructor is from a different sub-discipline so that

mentoring expertise and guest speakers cover a range of topics. With this number, faculty only will mentor roughly 15 groups which allows for more direct contact with the students and a better mentoring experience. The instructor core has remained consistent from the pilot to the full offering which has allowed for a depth of experience and intentional course revisions over time.

Teaching Assistants

There is a group of four teaching assistants working with the course, with one appointed as the lead. The teaching assistants are graduate students, and several have familiarity with the program as undergraduates. The primary role of the teaching assistants is grading student work. As can be inferred from the course components, there is some type of assignment due nearly every class meeting. The teaching assistants ensure that feedback is timely and informative. In addition to grading assignments, the teaching assistants also manage attendance (through the iClicker system), conduct office hours, serve as project mentors, and function as instructors during class exercises and field trips.

The lead teaching assistant has the additional roles of training the new teaching assistants, managing the assignments on the learning management system (LMS), and managing the peer evaluation from the students. The lead is often someone who has worked in the course prior (or worked in another course), and is highly organized. The training aspect can cover topics from assessing technical writing, navigating the LMS, and serving as a reference for grading issues. The lead will also post assignments and revise rubrics based on instructor input. Finally, the peer evaluation system (Teammates) generates substantial amounts of data that the lead synthesizes for the faculty.

External Advisors

The need for external advisors arose early during the development of this course. These advisors are in addition to the faculty and teaching assistant mentors mentioned above. The need is based on expertise and the limited number of faculty and teaching assistants in the course. There are two pools of advisors that provide this assistance throughout the course.

The first group is associated with university-level facilities and research. These advisors will identify current university and community needs that students can build their projects around and provide technical data throughout the project lifecycle. These advisors are volunteer so there are no expectations for their level of contribution. Some advisors will simply provide data while others may work with groups regularly or even help them to develop their projects into real applications.

The second pool of advisors is drawn from the senior-level CEE students. As part of their professional development requirement, they attend several class periods where the project teams share their ideas and receive feedback. This advisor pool is intended to provide additional insight into the projects, but they may only meet with a team one time. In addition to project advising, these meetings serve as a way from the new students to connect with older students. The seniors are encouraged to share their experiences with the program, internships, and future plans.

Hybrid Learning

While this class was developed for in-person delivery, we had to pivot to a hybrid modality due to the pandemic. Through this change, we discovered numerous challenges and advantages as we moved the course to a hybrid format.

A challenge in the first offering (Fall 2020) was the reduced capacity of classrooms. To accommodate the in-person students, we would not have a single room large enough. To overcome this limitation, we split the in-person students between two classrooms. We then broadcast camera and audio from one room to the second room. The faculty instructors were also split between the rooms and facilitated communication between the groups. Sometimes, this meant SMS text messages, but with some speakers, we switched the room's wireless microphones to allow for two-way communication. For the online students, we encouraged synchronous attendance, and assigned a teaching assistant to monitor the online room.

Another challenge is engaging the remote students in the classroom exercises and group project. As mentioned, the case studies would ask questions throughout their presentation and responses were collected through a remote system (iClicker). This system had recently changed to subscription-based app which allowed student to respond from anywhere in the world. The responses from both remote and in-person students would even be displayed together during the presentation. Since we set the expectation of synchronous attendance, we did not encounter significant attendance problems.

For the group project, we encouraged students to bring relevant technology and chargers to class so that they could hold group meetings during class even when their teammates were remote. Our project ideation sessions were moved fully online using breakout rooms to facilitate discussion and collaboration. The result was that we had very limited instances of remote students disengaging from their groups during the project. Field trips were actually enhanced for the same reason. All students would also tune into the online session where the tour guide would be the meeting host. This allowed social distancing with a large group, and allowing the guide to speak at a normal volume level.

Much of the course content was able to remain unchanged. The introduction and instructional videos were planned well before the pandemic and the group discussions were simply limited to each classroom or the online session. The computation skills activities were a bit more challenging with the online students since it often required screen sharing to troubleshoot problem.

One significant improvement brought about by the pandemic was the change to the guest speakers and the final presentation. With the higher degree of comfort with online meeting platforms, guest speakers could be more flexible with their availability, and we were no longer limited by the geography of the speaker. Prior to the pandemic, the final presentation was poster presentation, but was changed to an online, oral presentation. This move online accommodated the increased enrollment and number better than the previous poster presentation. Judges were able to quickly find the presentations they chose (using breakout rooms), and crowding was

never an issue. In addition, we were able to reach out to a broader alumni base who were not local to serve as judges.

While the move to a hybrid format took planning and effort, the transition in the first offering was positively received. We were able to maintain the content and objectives of the course for both the remote and in-person students. Project groups were flexible and the teamwork was overall positive with mixed mode groups. We were able to utilize more alumni for speakers and judges, and many returning judges preferred the online format. Many of the videos, online exercises, and alumni involvement developed for the pandemic will be retained even if we return to a fully in-person modality

Future development

While the course currently is meeting the assigned objectives, we acknowledge the need for continual improvement. One area we will work to improve is broadening the faculty involvement in instructor pool. A short-term goal is to begin introducing additional faculty into the course by serving as project mentors. Since this is the most significant aspect of the course, the faculty should be introduced to it early which they can focus on mentoring a limited number of projects. Over time their responsibilities will increase to allow them to serve as one of the lead instructors.

We will also begin to include more mentoring opportunities for upperclassman undergraduates. As graduates of this course move into the upper levels, they will be effective mentors for future classes. We want the upperclassman to take an intentional roll in near-peer mentoring and to provide an additional perspective both on the course project and the profession as a whole. We are considering a range of incentives to encourage this mentoring

In addition to enhanced undergraduate involvement, we want to include more alumni in the process. This will benefit the networking of the undergraduates while also improving the alumni connection to the program.

While data collection about student outcomes and feedback has been ongoing during the development, the majority of that data is for internal purposed. In future semesters, we will be assessing the course outcomes following institutional review board approvals so that data may be shared more broadly. We are also planning a longitudinal study to assess the technical writing ability across the curriculum.

Overall, this redevelopment has been positively received by the students, faculty, and alumni. While data collection is ongoing, student comments report positive experiences overall even if they do not appreciate the writing content. Some students continue their projects beyond the course as a project with the university, or in one case, developed a startup around their idea. The faculty are pleased with the presentation quality, and many of the case study presenters will recruit students for their research from the course. Alumni are appreciative of being included as judges and enjoy a high degree of flexibility when asked to be a guest speaker. While revisions will continue, this course currently meets the objectives that we created and is developing in a positive direction.

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