Integrating Service-Learning with Sustainability Engineering to Broaden Student Learning Outcomes

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Colleen generally loves being in academia, but is aware it can sometimes be a toxic environment. She has struggled her whole life with mental health and hopes to help her students have a better experience than she sometimes had.

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Abstract: Engineering emphasizes service and public welfare as core to the discipline. New generations of engineering students envision service and social impact work as significant components of their future careers. However, engineering education prioritizes traditional academic learning outcomes and approaches, which often do not include community engagement or service. Service-learning is a form of community engagement applied in classrooms that pairs well with traditional engineering academic learning outcomes. Incorporating this form of engagement can prepare students for their professional roles in the workplace. Here, we introduce an upper-division undergraduate elective civil engineering course that integrates both Service-Learning and the Engineering Design Process. The course involved working with a local community partner, who desired aid in designing and implementing an environmentally sustainable worm-composting bin. Students engaged in hands-on activities, including woodworking and engineering design, enhancing their practical skills and understanding of community engagement. In this work, we analyze pre- and post-course student survey responses and find increases in student knowledge, confidence (i.e., self-efficacy), and perceived usefulness of course concepts (i.e., academic learning outcomes). We also observe students exhibiting increased awareness and connection to their own social identities and recognition of them as strengths in their future careers (i.e., personal outcomes). Further, although we observe a consensus among young engineers regarding their dissatisfaction with current global and local sustainability efforts and feelings of climate anxiety, we also find increases in students' hope in spite of these barriers after the course (i.e., social outcomes). Cumulatively, these findings indicate that a service-learning course in sustainability engineering can lead to increased learning outcomes, which align with the current needs for and desires of early engineers.

1. Introduction

The growing urgency of environmental challenges, particularly the climate crisis, demands sustainability to be fundamental to the role of civil engineers. To ensure these challenges are approached equitably, engineers must view these issues with community engagement principles in mind [1]. Sustainability principles are a required part of ABET civil engineering program criteria [2] – a priority that has been echoed by the National Science Foundation [3] and within the United Nations' Sustainable Development Goals [4]. However, Swenty and Swenty (2024) evaluated the curricula of approximately 1/3 of EAC ABET-accredited civil engineering programs and found that sustainability-related courses are required in fewer than 20% of programs [5]. Further, engineering as a profession underscores public welfare and societal needs as core to the field's fundamental principles [6]. Yet, civil engineering curricula at higher education institutions have not historically prioritized service, community, or public welfare in their undergraduate courses [7], [8].

Service-learning (SL) is an educational experience that integrates disciplinary learning and community engagement [9]. When applied in a credit-bearing academic course, SL can be enacted such that students (a) participate in a service activity defined by a community goal and (b) reflect on their experience to deepen their course learning and gain a broader appreciation for their major [10]. This type of learning has been reported to lead to academic, social, personal and civic responsibility outcomes for students, as well as enhancing their understanding of the real-world while challenging their personal values [11], [12]. Further, Fuentes-Cid (2025) finds that integrating academic learning with community engagement allows for students to link their personal and professional cognitive development [13].

Despite established benefits, adoption of SL as a pedagogy in engineering programs has generally been slow, with one U.S. study identifying only 61 engineering-related courses among the 11,000 SL courses examined, highlighting a significant gap in the field [14]. However, notable programs representing progress exist, such as Purdue University's Engineering Projects in Community Service (EPICS) program and their affiliates [15], Santa Clara University's Service and Community Active Learning using Engineering Design (SCALED)[16], and the Louisiana State University (LSU) Community Playground Project [17], which emphasizes community-engaged learning in engineering. It is crucial for more engineering institutions to integrate SL into their curricula to emphasize the importance of service and environmental sustainability in engineering education. Together, these can play a crucial role in equipping young people with the knowledge and skills to meaningfully contribute to societal needs [18].

An adjacent issue persists in attracting and retaining a diverse student body in engineering [19], [20]. Namely, Hispanic/Latinx, African American/Black, Native American populations, and white women are underrepresented at each level of engineering in higher education (BS, MS, and PhD), earning approximately one half, one third, one fifth, and one half of all the expected degrees for each population group, respectively [21], [22]. However, Swenty and Swenty (2024) find social justice and diversity, equity, and inclusion (DEI) to be a required course in less than 3% and 10%, respectively, of civil engineering programs [5]. Integrating core engineering principles like service into curriculum is particularly well suited to address these challenges, as helping society and service are known drivers for historically marginalized groups choosing to study engineering [23], [24]. Further, environmental concepts which highlight human concerns, such as the effects of material sustainability, have also been shown to be a key avenue to engage a new generation in engineering [25], [26]. Altogether, these concepts can support increased diversity and inclusion in engineering to expand the intellectual talent pool, broaden perspectives brought to problem solving, and strengthen the workforce.

In this work, we evaluate an upper-division undergraduate elective civil engineering course that utilizes an SL approach to teach course content that emphasizes environmental sustainability and environmental justice concepts. We examine quantitative responses from pre- and post-course surveys from the students to measure student academic learning outcomes. Next, we analyze long-form qualitative responses to questions related to their motivations for selecting engineering, social and personal identities within engineering, goals for their careers, and their feelings on current environmental sustainability efforts. The initial long-form responses are paired with shifts in responses received at the end of the course to examine student learning outcomes.

2. Methods

2.1. Course Motivation

We introduced a pilot upper-division undergraduate elective civil engineering course over a 10-week quarter, which integrated SL principles. The motivation for this approach was to (1) provide a new community engagement opportunity for students to attract diverse students and broaden their academic experience and (2) to offer more hands-on educational opportunities in preparation for the workforce in response to earlier anecdotal student feedback. Throughout the course, students worked with a local community organization to design an engineered alternative for the community partner's operation. The course was structured to provide students with hands-on experience focusing on how environmentally sustainable solutions can be designed and implemented in the community.

2.2. Course Overview

Lecture and homework content included practicing the key steps of the engineering design process, reviewing effective community engagement practices, discussing environmental and social justice cases within engineering, learning professionalism through project management principles, and practicing Life Cycle Assessment (LCA). The course activities included lectures, homework assignments, woodworking lab activities, and assembling a product for the community partner. The course concluded with the students completing an engineering design and implementing the design on-site with the community partner. Each of the six stages of Bloom's taxonomy was integrated in the course [27].

Ten undergraduate students participated in the course, ranging from 2nd year to 5th year undergraduate civil engineering students. The course provided upper division elective credits, which can be applied to their graduation requirements, demonstrating the department's commitment to the course. Students learned woodworking skills from the university's Engineering Student Design Center (e.g., using equipment like saws, planers, and power tools to build their final design). To address the goals of our community partner project, discussion of constructability and vermi-composting were added as lecture topics. The learning objectives of the course included:

1. Engage in hands-on engineering design through service-learning to implement environmentally sustainable solutions that address community needs.
2. Apply and practice the key steps of the engineering design process to develop effective and practical solutions for real-world challenges.
3. Develop skills in effective community engagement by collaborating with a local partner to ensure designs align with stakeholder needs and expectations.
4. Analyze environmental justice cases to understand the intersection of equity, sustainability, and engineering practice.
5. Utilize quantitative methods to evaluate and enhance the sustainability of engineering projects.
6. Collaborate with a local community partner to design, develop, and implement an engineering project that meets the organization's goals and supports the community.
7. Complete an end-to-end engineering design project, including on-site implementation, to gain practical experience and refine professional skills.

2.3. Course Assignments

The course assignments began with students individually researching the community partner's worm composting bin. The second instructional week included a field trip to the community partner's site, where students presented questions from their first assignment. Students were provided with example questions they should be expected to have answered by the end of the field trip, including: "what is the primary service(s) this worm bin provides?", "who does the worm bin service?", "what are the dimensions (height, width, length, and thickness) of the current worm composting bin?", "provide at least two goals and two limitations for the worm composting bin project".

Students then individually created a preliminary design based on their investigations of project history, goals, and constraints. These designs were shared with the community partner for review and to be discussed altogether during a class period. Following the discussion, the class and community partner collaboratively developed a priority list categorizing design aspects as either essential (required for the final design) or non-essential (optional, but beneficial if feasible to achieve in final design).

To explore LCAs, students were individually tasked with comparing the environmental impacts (e.g., kg of greenhouse gas (GHG) emissions) of two building materials: cement/concrete and wood/soft lumber. Here, students evaluated the environmental trade-offs in material selection for design projects. Students practiced applying principles of community engagement and environmental justice, by analyzing and reflecting on one local and one global case study.

Finally, the class split into two groups to focus on separate design components: the base bin and the lids. Each group developed a detailed final design that included materials, cost estimates, dimensional sketches, and justifications for how their designs addressed the agreed-upon essential requirements. Each group designated a communication leader role to ensure regular design coordination between both groups. From this point forward, all worm bin design related tasks were completed in groups during laboratory instructional periods (both on campus in our lab classroom and on site at the ecological garden). Students met with our community partner a total of three times prior to installation of the worm bin on site, to ensure maintenance of expectations and clear communication.

2.4. Community Partner Collaboration

To establish a community partner, we collaborated with the Public Scholarship and Engagement office at the University [28], who advertised the course to their network of local partner organizations. We distributed a digital flyer highlighting the course and project collaboration, along with a form for groups to express interest and propose potential projects. A Request for Proposal (RFP) detailing (a) the scope of work, (b) background, (c) expectations, (d) examples of potential collaboration projects, (e) timeline for community partner, and (f) course timeline for students was also included in the email. This approach garnered interest from four organizations. Ultimately, our final community partner was selected based on project feasibility and schedule compatibility. For the first course offering, our community partner was a local ecological garden that facilitates local K-5 student learning and sustainable gardening.

To communicate and manage expectations with our community partner, we developed a list of expectations, including (1) a desire to work with undergraduate civil engineering students, (2) an understanding and flexibility in the event that the project may not be completed until the following term (instructors guaranteed project completion even if students were not able to finish in one term), (3) coordination with the instructors before and after the course, (4) minimum of three attendances at course instructional periods to communicate project goals with students and provide feedback on project design, and (5) an approximate budget for materials and equipment that the instructors covered. To maintain a mutually beneficial partnership with the ecological garden and to guarantee project completion, course instructors funded and assigned the graduate student co-instructor to continue work on this project over the following two quarters to ensure the project was properly established after the end of the term. Future course iterations could explore hiring and funding select former students as undergraduate researchers through independent study units, as a way to ensure project functionality post-term.

2.5. Course Project – Worm Composting Bin

The instructors determined the community partner and project in advance of the course start to ensure all the tools and safety requirements necessary to build were established. Our community partner proposed a redesign of their current wooden worm composting bin for the project. This composting bin is used as a sustainable gardening approach and an interactive element for their K-5 student field trips. This bin, visited by over a thousand students each year, is used to help introduce topics like reducing food waste, addressing food justice, and reducing climate impacts. However, the ecological garden workers faced challenges with the existing worm composting bin, including deterioration, heavy lids, and walls too high for smaller children. These issues limited the bin’s accessibility and functionality.

The course tasked engineering students with designing and installing a new bin that met the community partner’s aims. In order to meet the course timeline, the students worked with the community partner to prioritize their goals into essential and non-essential categories. Essential goals, such as waterproofed lids, lighter and more ergonomic lids, and a moist and cool environment for worms, were prioritized in the final design. The students also creatively addressed some of the non-essential goals. For example, to make the bins less intimidating for K-5 students who are scared of insects (a non-essential goal according to our community partner), our engineering students painted cartoon-like images of the types of insects expected to be seen in the bin, making it more inviting.

2.6. Shared Principles of the Engineering Design Process and Community

The course centered most lessons and assignments on the Engineering Design Process to reinforce core engineering principles (Fig. 1a). This process served as a guideline for the instructors when designing the course assignments and for the students when designing their final project. As part of the course, students started with the “Ask” phase by interviewing the community partner about their goals for and current challenges with the worm composting bin. Then students were guided to perform “Research” to supplement their interview findings. Using their research, students entered the “Imagine” stage where they developed their own individual preliminary designs, which were shared with the community partner at the ecological garden. The community partner provided feedback to the students, which they incorporated into their group "Plan" for their final design. Once the plans were developed, students presented their final design proposal to the community partner. Finally, students entered the "Create" phase where they utilized woodworking equipment to bring their designs to life. Practitioners of community engagement [29] follow a similar process to engineering design [30], to ensure community expertise and community objectives are central to the work (Fig. 1b).

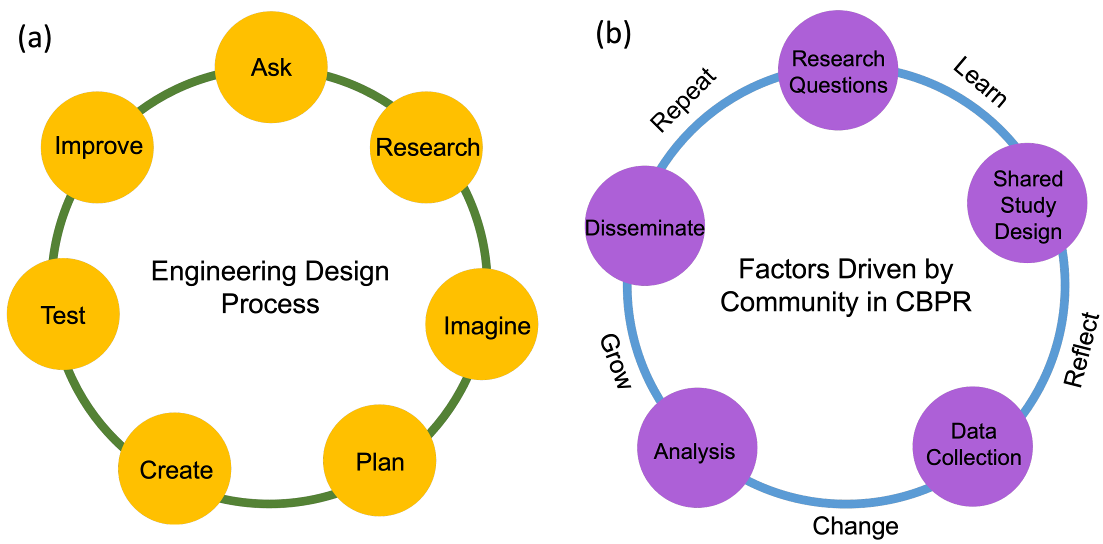

Fig. 1. (a) The engineering design process, modified from Carberry et al. 2010 [30] and (b) factors driven by community in Community-Based Participatory Research (CBPR), modified from Milton et al. 2023 [29].

By following the Engineering Design Process, students practiced the factors that drive community engagement throughout their design process (e.g., community partner's expertise was central to the design process, the design was co-created with the community partner, students and the community partner reflected together). Students completed "Test" and "Improve" phases through reflections in their final project reports. As discussed with the community partner in advance, the instructors continued to work with the ecological gardens to learn about how the project tested with time. These findings were shared with the students in the course after the end of the term to emphasize the importance of these stages and continuous learning. Four students voluntarily participated with the instructors, five months after the course completed, to implement improvements (including reframing and sealing of lids to ensure a watertight system).

2.7. Course Survey

Quantitative and qualitative assessment of the students' experiences included pre- and post-course surveys to inform impact on learning outcomes (e.g., ability to apply knowledge), personal outcomes (e.g., sense of self-efficacy and belonging), and social outcomes (e.g., reduced stereotypes). The survey asked the same quantitative and qualitative questions at the beginning and the end of the academic quarter (10 weeks apart). The instructors reviewed informed consent with the students before administering the survey and obtained it from all participants. Students provided this data anonymously, as the survey first asks students to create a unique reproducible identifier to ensure confidentiality of their responses. The first series of prompts were quantitative, using a 0 to 3 adaptation of the Likert scale to assess students' sense of knowledge about, confidence in applying, and perceived usefulness of 14 topics that are introduced in the course. Following this, students responded to a set of open-ended questions where they are encouraged to write out longer personal responses (Table 1).

3. Results

3.1. Quantitative Responses

3.1.1. Course concepts and stage of intervention

Fig. 2 outlines the intervention approach used to teach each course concept to measure student learning outcomes. Although some concepts may appear similar (e.g., sustainability vs. sustainability in engineering), we intentionally separated these items to assess whether students could grasp the nuances between general and discipline-specific concepts. For example, sustainability has become a widely used word in many fields, but it is essential for civil engineering students to understand the unique role their discipline plays. We introduced the general concept of sustainability by discussing the history of major global sustainability initiatives, including the United Nations' 1987 Brundtland Report [31], which formalized the Three Pillars of Sustainability framework. This framework emphasizes the importance of balancing three interconnected measures: (a) environmental, (b) social, and (c) economic. Students applied this framework when performing initial general analyses of sustainability within their designs. The discipline-specific concept of sustainability, referred to as sustainability in engineering, was taught through tools like LCAs, which help students measure and implement sustainability principles within their disciplines. To deepen this disciplinary knowledge, instructors also discussed the history and current practices of Industrial Ecology, the field from which LCAs are derived. Fig. 2 groups concepts into general and discipline-specific pairs, with each pair highlighted in a particular color; concepts shaded in grey do not have a corresponding general or discipline-specific counterpart for comparison. These distinctions between general and discipline-specific concepts were addressed in detail during lectures and assignments.

Concept	Intervention Approach				
	Lecture	Lab	Assignment	Presentation	Final Report
Sustainability (g*)	x		x		
Sustainability in Engineering (d**)	x	x	x		x
Life Cycle Assessment (LCA) (g)	x	x	x		x
Industrial Ecology (d)	x				x
Social Justice (g)	x				
Environmental Justice (d)	x		x		
Composting (g)	x				
Vermi-composting (d)	x	x	x	x	x
Engineering Design Process	x	x	x	x	x
Community Engagement	x		x		
Service-learning (SL)	x		x		
Science Communication	x	x		x	
Constructability	x	x	x		x
Professionalism	x			x	

*a general concept is indicated by (g).
**a discipline specific concept is indicated by (d).

Fig. 2. Course concepts measured in Fig. 3 and their corresponding intervention approaches. Note: This figure groups pairs of general (g) and discipline-specific (d) concepts, with each pair highlighted in a particular color; concepts shaded in grey do not have a corresponding g or d counterpart for comparison.

3.1.2 Discussion of quantitative assessment results: overall comparison

Quantitative assessments showed increases in students' knowledge, confidence and perceived usefulness of most course concepts, consistent with findings from Langhout and Gordon [11], that highlight how SL enhances academic outcomes. The students' quantitative survey results are displayed in Fig. 3. Before the course, students found all topics useful on average (i.e., a score of 1 or greater). While most assessed categories increased, students' scores remained the same with regards to usefulness of the engineering design process and professionalism (average results are high at 2.78 and 3.00, respectively). Students demonstrated average increases in score by 1 or greater in five concepts: their knowledge and confidence of Industrial Ecology, constructability, SL, vermi-composting topics, and their LCAs.

Industrial Ecology is an essential concept for sustainability-focused engineers and has been defined as “the science of sustainability” [32]. Despite noting an average usefulness score of 2.00 for Industrial Ecology before the course started at that time, students did not feel knowledgeable or confident on topics related to Industrial Ecology (average scores of 0.56 and 0.56, respectively). By the end of the course, the Industrial Ecology knowledge and confidence scores were 2.00 and 2.56, respectively. Similar trends were noted for other categories as well.

For example, the usefulness scores for SL and vermi-composting were 1.67 and 1.00 at the onset of the course, but the students did not feel knowledgeable or confident (knowledge and confidence in SL had an average score of 0.67 and 0.89, respectively, and vermi-composting had an average score of 0.56 and 0.67, respectively). By the end of the course, the knowledge and confidence for SL increased to 2.22 and 2.44, respectively, and the knowledge and confidence for vermi-composting increased to 2.22 and 2.00, respectively. While these results would suggest a great relative change during the course, we note that results are reflective in part of the small sample size in which a single respondent can greatly influence outcomes.

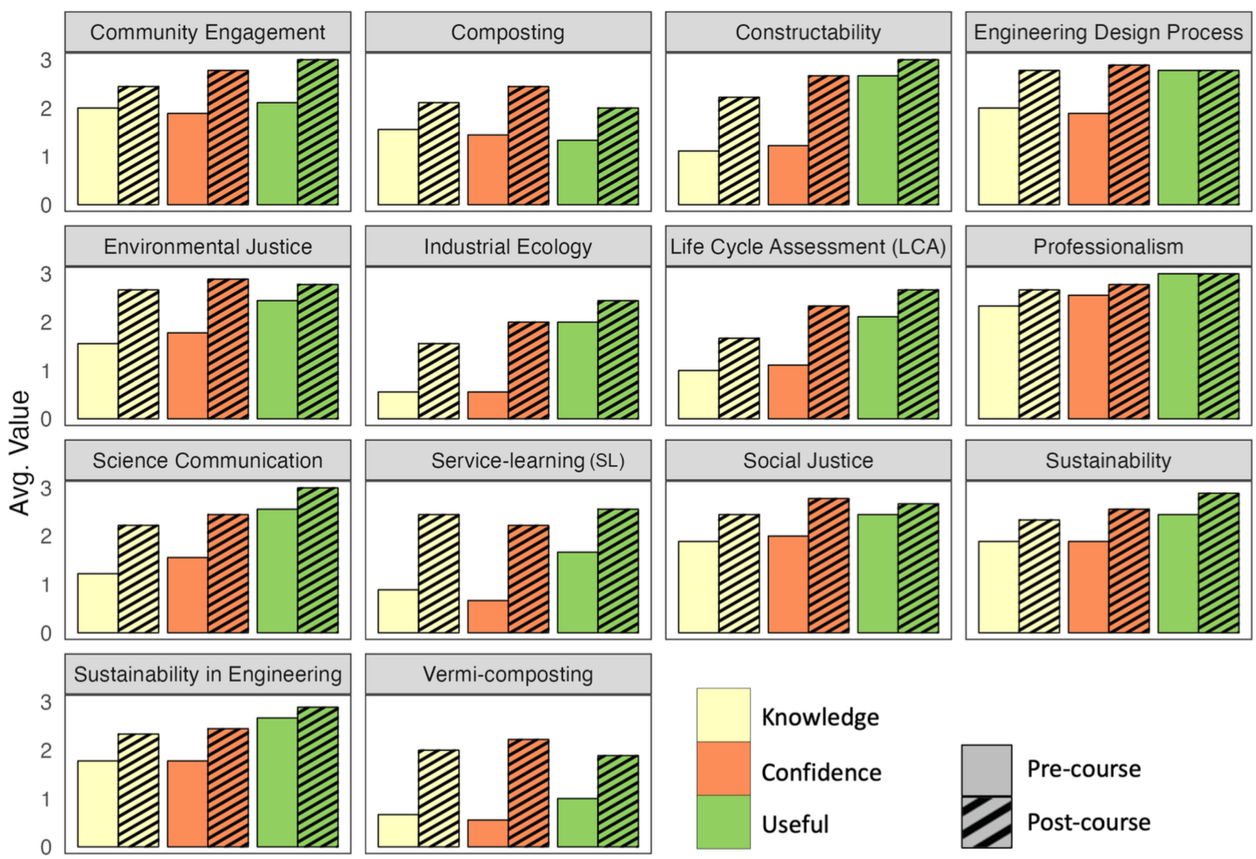

Fig. 3. Average student response scores self-assessing their knowledge, confidence, and usefulness of a concept both before (pre-course) and after (post-course) instruction.

3.1.3 Discussion of quantitative assessment results: discipline-specific vs. general concepts

This discussion focuses on concepts with both general and discipline-specific counterparts: (a) sustainability vs. sustainability in engineering, (b) LCA vs. Industrial Ecology, (c) social justice vs. environmental justice, and (d) composting vs. vermi-composting. As anticipated, the pre-course survey showed that students reported higher knowledge and confidence for all general concepts compared to their discipline-specific counterparts (e.g., sustainability scored higher than sustainability in engineering). However, no clear trend was found regarding their perceived usefulness of discipline-specific concepts compared to their general counterparts. Notably, all discipline-specific concepts showed at least a 38% increase in usefulness value relative to students' reported knowledge and confidence values. This finding suggests that students recognize the value of gaining depth in industry-specific concepts while still developing their proficiency in those areas.

In the post-course survey, students reported higher knowledge, confidence, and usefulness values for all general concepts compared to discipline-specific ones, except in one instance, social justice vs. environmental justice. For this pair, students reported environmental justice (the discipline-specific concept) as higher in knowledge, confidence, and usefulness than social justice (the general concept), even as social justice also experienced increased values from pre-course survey responses.

3.2. Qualitative Responses

In addition to the quantitative results shown in Fig. 3, qualitative results were collected through short answer survey questions. Effectively capturing results from a small sample size (i.e., 10 students) requires a detailed analysis of the nuanced thoughts and feelings of the student participants. As such, the qualitative results are discussed in terms of common themes among student responses and also through individual case studies. Table 1 displays common themes from pre- and post-course survey responses for each question. In this work, a "theme" is defined as a topic mentioned by two or more students. Question 1 asked students for the year of schooling they are in and is not included in Table 1.

3.2.1. Responses to Question 2

When asked, ***"What was your motivation for selecting engineering as a major?"*** at the start of the course, the most frequent response was related to sustainability and climate change, mentioned by four students. Social impact, problem-solving, and the practicality of the discipline each received mention by three students. Two students mentioned creative aspects as their motivators. At the end of the course, experience with hands-on skills arose as a new theme among three students as motivators for their careers. This learning outcome can be directly attributed to the project that students co-designed and built with the community partner. The theme of social impact remained constant in frequency, but two of the students had not previously mentioned this in their pre-course survey response. Further, one student detailed a broadening of their perspective, which aligns with Fuentes-Cid's [13] findings of increased personal and professional cognitive development through integrating course concepts with community engagement:

- *"I gained a much greater perspective on the impact my job as a (potential) engineer has on social and environmental issues. I think this course adjusted how I see my role and I recognize how there should be many considerations, in terms of the engineering design process, environmental justice, and community engagement, that I take into account when approaching work."*

3.2.2. Responses to Question 3

When first asked, ***"Do you believe that aspects of your personal/social identity (e.g., personality, hobbies, gender, ethnicity, sexual orientation, culture, ability status, socioeconomic status, religion/spirituality, nationality, etc.) are/will be valuable in your role as an engineer? If so, how? If not, why not?"***, seven students answered yes. Of the yes responses, four mentions of personal identities, such as personality and hobbies, and three mentions of social identities, such as race, gender, and religion were discussed. Personal identities refer to individual personal traits that distinguish a person from others (e.g., personality, hobbies), while social identities are defined as aspects of oneself which derive from membership in social groups (e.g., race, gender, ability status). Three students responded no to this question, noting their social identities such as sexual-orientation, ability/disability, race, and gender as not being valued in their discipline. An excerpt from student responses is provided below.

- *"No. We don't really live in a society to accommodate or allow queer, colored, or disabled people to flourish. I have to constantly put myself down because of my capabilities and sexual orientation. Engineering culture especially is very 'in the box'…"*

Table 1. Frequency of common themes mentioned among students' qualitative responses to pre- and post-survey questions.

Question	Pre-Survey		Post-Survey	
	Theme	Number of Student Mentions	Theme	Number of Student Mentions
Question #2: "What was your motivation for selecting engineering as a major?"	Sustainability & Climate Change	4	Hands on skills	3
	Practical Job	3	Sustainability	3
	Problem-solving aspects	3	Social Impact	3
	Social impact	3	Practical Job	2
	Creativity	2		
Question #3: "Do you believe that aspects of your personal/social identity are/will be valuable in your role as an engineer? If so, how? If not, why not?"	Yes, Personal Identities	4	Yes, Social Identities	5
	Yes, Social Identities	3	Yes, Personal Identities	2
	No, Social Identities	3		
Question #4: "How do you envision using your engineering degree?"	Social Good & Community Impact	4	Sustainability	7
	Practical Aspects	3	Social Justice & Community Impact	4
	Sustainability	2		
Question #5: "Describe your thoughts and feelings about current sustainability challenges and our ability as a society to tackle them."	Dissatisfied with current sustainability efforts	8	Hope in spite of fear	7
	Climate Anxiety & Hopelessness	5	Dissatisfied with current sustainability efforts	6
	Hope in spite of fear	2	Sustainability efforts must incorporate community engagement	2

After the class, students' responses shifted from focuses on personal identities to emphasizing their social identities. Hobbies and personality are mentioned again, twice. Five students elaborated on how they feel their social identities are valuable in spite of engineering not yet being a field that values these identities. Through the course, students connected with their own social identities and now recognize how these identities can be strengths in their future careers, emphasizing connections between personal and professional cognitive development [13].

- *"I believe my background does play a role in engineering because our lived experiences can shed light on aspects and after-effects of engineering projects. Through this class, I was really able to empathize with marginalized groups who were negatively impacted by engineering projects. I recognize the duty we have as engineers to consider diverse perspectives in our work now more than ever."*

It is important to note that one student mentioned no change in their feelings, noting they still do not believe their social identities are valued in engineering. Because only one student mentioned this, it is not included as a theme in Table 1.

3.2.3. Responses to Question 4

The most frequent (four mentions) pre-course survey response to the question, ***"How do you envision using your engineering degree?"***, involved some kind of social impact and community. For example, a student noted:

- *"I hope to use my degree to create and design things that help in any aspect whether that be the world, a community, etc."*

Three students mentioned practical aspects like designing high rise buildings or construction management as their career vision. Two students mentioned sustainability efforts as an area they envision their degree being used.

The mention of sustainability increased from two students in the pre-course survey to seven students indicating it as paramount to their future careers in the post-course survey. Students named specific concepts from the course such as Industrial Ecology and LCAs as tools they plan to use in their careers, underscoring the importance of sustainability concepts for current and future engineers. Although students maintained their vision of social impact, their responses shifted from broad phrases like "help" and "taking care" to mention of applying specific concepts like "environmental justice" and "community engagement" in their future careers. Recognizing the necessity of integrating these concepts into their engineering professions exemplifies a deepening of their understanding of the complexity of real-world issues, matching the findings from a previous study [12]. One student plans to embody a core principle of community engagement, recognizing community expertise and knowledge, which should be taken into account during the inception of any project [33]:

- *"…I also want to be an engineer that uplifts the community and I hope to take into account all sorts of community/social impacts before moving forward with any projects."*

3.2.4. Responses to Question 5

The themes in question 5 received the highest frequency of responses from students compared to all other questions. This outcome indicates there is consensus among students when it comes to their feelings about the prompt, ***"Describe your thoughts and feelings about current sustainability challenges and our ability as a society to tackle them."*** Eight students mentioned a notable level of dissatisfaction with current sustainability efforts.

- *"…it's evident that those who are in positions to do anything about it choose not to. I also think that our education has failed us because sustainability issues and concepts are not taught generally speaking."*

Among these responses, students alluded to or explicitly mentioned feeling a level of Climate Anxiety or hopelessness (five mentions). Climate Anxiety is an adaptive psychological response to the real threat of climate change [34]. Harmful impacts on physical health, mental health, and social relations have arisen as a result of the global climate crisis [35]. Worrying for future generations, lack of adequate responses to climate change, and general feelings of helplessness and disempowerment are common themes among those who experience climate anxiety [36]. Two students noted maintaining hope in spite of the fear and anxiety surrounding sustainability and climate change.

After the course, the theme of hope in spite of fear grew and was mentioned in seven student responses. Students displayed a deeper understanding of the complexity surrounding climate change and sustainability in their responses, which yielded some optimism.

- *"I think there may be many people who are apathetic to sustainability and are more concerned with short-term rewards."*

Even so, the general consensus of dissatisfaction with current campus, regional, national, or global sustainability efforts and climate action remained a major theme, with six mentions. Finally, a new theme emerged for two students regarding community engagement as necessary to address sustainability challenges, highlighting the influence of an SL approach to the class.

4. Conclusion

Engineering education must shift to meet the needs of a new generation. Engineering students increasingly come from diverse backgrounds and want to use their degrees to promote social change, engage with their communities, and take climate action. However, the current engineering curriculum is not prepared to provide students with the necessary knowledge and skills to do so with equity and inclusion in mind. One approach to address these aims is to incorporate the fundamental engineering principle of service, through community engagement, along with sustainability engineering topics. We provide an example of how an SL approach in engineering can work well together to address these desires. Consistent with the literature, our analysis of student survey responses suggests these methods deepen discipline-specific academic outcomes. At the same time, our findings indicate this type of learning to increase students' sense of belonging to their major (e.g., increase in students' belief that their social identities are valuable as engineers) and promote a hopeful spirit in spite of climate anxiety and dissatisfaction with current sustainability efforts. These results show enhanced social, personal, and professional development outcomes for students, while also deepening their understanding of the real-world. Due to the pilot nature of this course, this study was limited to 10 students; additional student perspectives are a necessary component of future work.

An unexpected takeaway from student responses is that they are experiencing climate anxiety. Worrying about the outcomes from climate change and environmental deterioration was mentioned by almost all students. And although they have contributed the least to the climate crisis, they are disproportionately impacted by it. Even so, young people are the ones leading climate action and activism, globally, in schools, and within their communities. Schools and educators are uniquely positioned to support young people by providing the knowledge and skills to make students technically competent and personally empowered to take climate action. Engineering education must adapt to join in this educational and societal transformation to produce a technically rigorous, sustainability focused, and socially conscious engineering workforce. Incorporating SL into the engineering curriculum may further enhance students' understanding and commitment to sustainability and social responsibility. These pedagogies, with their emphasis on real-world application and community engagement, could serve as impactful methods to deepen student learning and foster the skills necessary to address the complex challenges posed by climate change.

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