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Complete paper (evidence-based practice): Integrating Sustainability into Engineering Education: The Impact of Complementary Field Activities on Student Engagement

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Integrating Sustainability into Engineering Education: The Impact of Complementary Field Activities on Student Engagement

Abstract

This **Complete Research** paper details the design and implementation of the Complementary Field Activities (CFAs) as an educational framework for engineering first year students that promotes sustainability and student engagement, while providing personalization and exploration.

Sustainability is a critical global challenge, and shaping future engineers to integrate sustainable practices is essential for addressing this issue. However, students often face an overwhelming array of educational opportunities, leading to information overload that can hinder their ability to engage meaningfully with high-impact experiences. In an environment where students are constantly bombarded with extracurricular options—from research projects to social events—navigating these opportunities becomes a challenge, especially for first-year students.

To counteract this and promote engagement with sustainability initiatives, we have developed the Complementary Field Activities (CFAs) framework. The CFA module empowers students with a structured, yet flexible, choice-based system that allows them to tailor their learning experiences according to their interests. By giving students autonomy to select from a curated set of sustainability-focused activities, CFAs provide a balance between guided learning and personal exploration, ensuring that students can engage with impactful educational experiences without feeling overwhelmed.

CFAs are university-wide educational events that connect first-year engineering students with faculty, staff, and internal organizations to provide hands-on involvement in sustainability initiatives on campus and beyond. These activities are categorized into three types: social, knowledge, and encounter.

Social CFAs involve campus-wide networking events, workshops, and activities led by sustainability-focused student organizations and community groups. Knowledge CFAs consist of 50 minute workshops that feature a combination between lecture and interactive, hands-on applications of sustainability concepts, led by faculty and staff engaged in sustainability research and practice. Encounter CFAs offer students site visits to observe and engage with sustainability practices in action, such as campus recycling centers or energy-efficient buildings.

The CFA framework was integrated into the interdisciplinary course *Engineering in the 21st Century (E102)*, involving 726 first-year students across 10 sections taught by three instructors. Students were divided into two groups. Group A received streamlined access to CFAs, including a curated list of activities and regular reminders via the learning management system (Moodle), with access to both in-person and asynchronous CFAs. Group B, in contrast, received information about CFAs only via Moodle posts and verbal communication during class without asynchronous options or structured reminders. Both groups were required to complete three CFAs of their choice and submit photos and reflections on their experiences.

Two instruments—pre-course and post-course surveys—were used to evaluate students' understanding and engagement with sustainability. The pre-course survey assessed their initial knowledge and interest in sustainability, while the post-course survey evaluated their reflections on sustainability concepts and how the CFA framework influenced their involvement. Preliminary results indicate that most students in both groups lacked prior knowledge of campus sustainability initiatives but expressed a strong desire to get involved. Group A, which received regular communication and reminders, attended more CFAs and showed higher participation in sustainability initiatives.

These findings suggest that integrating structured communication and flexible learning formats into the curriculum significantly enhances student engagement with sustainability efforts. The CFA framework not only fosters collaboration between students and campus sustainability partners but also encourages students to reflect on how their future engineering careers can contribute to sustainable development. This educational module provides a meaningful interdisciplinary learning experience that extends beyond the classroom, positioning students to become proactive contributors to sustainability in their professional lives.

Keywords: Complementary Field Activities (CFAs), Sustainability Education, First-Year Engineering Students, Student Engagement, Educational Framework

Introduction

This is a complete evidence-based practice paper. Engineering education aims to equip students with essential skills including intentional learning, curiosity, and effective collaboration [1], [2], [3] in addition to extensive training in mathematics, sciences, and engineering-specific topics. The goal is to provide a strong technical foundation and introduce essential skills for professional and personal development by integrating core courses with concepts from engineering education [2]. These essential skills help students address pressing 21st-century challenges, such as sustainability [4], [5], as they navigate the growing complexities of modern industries in their careers. Curiosity, intentional learning and effective collaboration go beyond traditional academic instruction, allowing students to develop expertise through experience and the learning processes [6]. Several strategies have been applied to develop curiosity and intentional learning in the classroom such as reversed (or flipped) classrooms [7], [8], [9], “Choose Your Own Adventure” [10], [11], [12], [13], and High Impact Experiences (HIEs) [14], [15].

Reversed or flipped classrooms aim to engage students with the course material before class, then utilizes the class time to foster interaction between their peers, their instructor, and the main focus of the activity, significantly impacting collaboration, intrinsic motivation and curiosity of the students [7]. The "Choose Your Own Adventure" [10], [11], [12], [13] framework provides students with a selection of activities that all lead to the same learning outcomes. This allows them to personalize their learning by choosing content and activities that align with their interests. Such a framework is especially beneficial for engineering students to help them build expertise in key concepts and develop interests that can be applied to their specific disciplines [6]. Fostering engagement with their community through shared interests and experiences promotes a sense of belonging. This sense of belonging has been linked to higher

retention rates in academic programs and is essential for promoting students' well-being and achievements [16], [17].

High impact experiences (HIEs) are immersive activities that offer students opportunities to deepen and apply knowledge both in and out the classroom [18]. HIEs empower students to learn and grow through structured critical reflection, collaboration with partners and peers, and connections that help them define goals across their academic experience [14]. Examples of HIEs include internships, study abroad programs, capstone design projects and undergraduate research [15], [19]. These HIEs can concentrate on a particular area of focus, such as community leadership, environmental issues, or general well-being [20]. The educational benefits of HIEs are however hindered by a lack of flexibility and accessibility, as they are often one-time events or have limited availability within the academic cycles [14], [26].

To this end, we propose a novel educational module, named Complementary Field Activities (CFAs), designed to promote participation and engagement in HIEs within a structured framework. This study examines the development and implementation of the CFAs and their effectiveness in broadening students' interdisciplinary perspectives and engagement with learning and campus resources.

The CFAs were all designed around one main 21st-Century Grand Challenge, Sustainability. Efforts to address environmental issues, such as energy use, have indeed been a large focus in academia [20]. This focus is evolving to empower learners to address complex sustainability challenges and make informed decisions that promote not only environmental stewardship, but equity and intergenerational responsibility [22]. However, research shows that engineering students associate sustainability mainly with resource conservation and eco-systems preservation, overlooking the social and economic dimensions. This limited understanding underscores the importance of presenting sustainability as a holistic concept that can be defined by an equilibrium between three pillars, namely environmental, social and economic [23], [24].

Educational modules and experiences that align with course learning outcomes and a holistic concept of sustainability can be integrated into engineering courses to support sustainability as a whole [25], [26]. For instance, sustainability-focused case studies have been introduced in lab settings to address real-world sustainability challenges and enhance students' understanding of the impact and influence engineering has on global issues [27]. Such efforts aim to equip students with the knowledge needed to make advancement in their field and contribute to cohesive, sustainable solutions.

Herein, we discuss how the integration of CFAs into the first-year engineering curriculum fosters student engagement in sustainability-related activities by exploring sustainability from multiple perspectives across campus.Specifically, we aim at understanding the following research questions:

1) What is the effect of assigning a curated list of activities in a Learning Management System (LMS) *vs.* in a spreadsheet format in student participation and assignment completion?
2) What is the impact on students' satisfaction regarding course accessibility if the activities are offered synchronously and asynchronously?
3) How does curating and offering opportunities for students to engage with sustainability practitioners on campus affect their appreciation for sustainability?

Theoretical framework

The CFAs are based on three foundational aspects, namely (i) student participation, (ii), interdisciplinary efforts and (iii) flexibility, that create opportunities for interaction and deeper exploration of sustainability as a holistic concept. These aspects can be developed through HIEs, hands-on activities and immersive exploration, and flexibility through in-person and virtual experiences so students can access the content regardless of their schedule (Fig. 1a). Additionally, the CFA framework takes advantage of existing events and opportunities created by campus partners and research programs on campus. All these activities promote the alignment between the learning outcomes of the course and the integration of sustainability in the curriculum. Research shows that student participation and engagement in such activities promote academic growth and foster a sense of ownership [3], [16], [17]. Interdisciplinary perspectives, especially within sustainability-related projects, help students broaden their understanding and develop solutions that extend beyond technical tasks [6], [22], [28].

The CFAs were organized into three categories: Social, Knowledge, and Encounter (Fig. 1b). This categorization aimed to 1) simplify the decision-making process for students, reducing the cognitive load involved in choosing activities, and 2) offer a broad framework for campus partners and faculty to align their activities with the CFA structure.

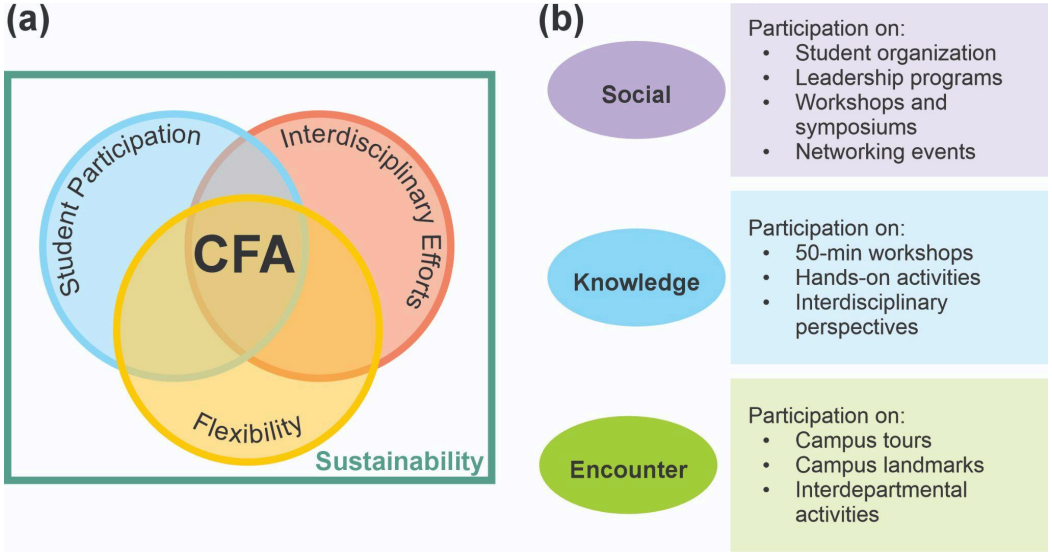

Figure 1. (a) Graphical representation of the foundational pillars that are embedded in the Complementary Field Activities (CFAs), and (b) Description of the Social, Knowledge, and Encounter CFAs.

Social CFAs take advantage of campus-wide sustainability related events to connect students to organizations that promote sustainability and career development. By fostering networking, students are given the opportunity to engage in on-campus sustainability initiatives. Examples encompass lectures on climate change, sustainable laboratories implementation, library resources for sustainability topics, among others. The events are organized through

collaborations with the institution's library, the sustainability office, and multiple research groups at our institution. These social CFA workshops and information sessions offer a broad range of topics meeting both general and specialized interests, to engage students and encourage participation in the activities and beyond.

Immersive sustainability experiences are provided through Encounter CFAs and give students the opportunity to observe sustainable initiatives and facilities in action. These facilities, which are mostly run by the university but also include some student-led initiatives, give groups of up to 20 students the chance to tour the facility, interact with staff and interns, and ask questions. The tour of the local compost facility, where students can see the entire on-campus composting process, is a well-liked illustration.

Knowledge CFAs are 50-min workshops on sustainability-related topics that connect university partners with students. The format includes a 15-min presentation by the university partner, introducing students to new sustainability concepts or research, followed by a 20-min hands-on activity during which students actively apply the concepts they just learnt. The hands-on learning experience aims to foster curiosity and to promote students' engagement and understanding of the sustainability topic. At the end of the workshop, 15 minutes are dedicated to students' reflection and questions, strengthening partner-students connection.

Implementation methodology

Around 700 first-year engineering students enrolled in the interdisciplinary course, E102: Engineering in the 21st century, participated in this study. E102 is a required introductory course for all engineering students that aims to showcase the various engineering disciplines and introduce the 14 Grand Challenges of Engineering to first-year undergraduate students in engineering. The 14 Grand Challenges are clustered in four main themes, (1) sustainability, (2) security, (3) joy of living, and (4) health. These themes bring together different engineering solutions and approaches while maintaining a holistic view of engineering. E102 also aims to help students navigate the diversity of engineering disciplines at NC State University and encourage them to explore their interests and potential career paths in engineering.

In fall 2024, E102 was offered to 17 sections with approximately 70 students per section. The CFAs were implemented in 10 sections (out of the 17), which were facilitated by three different instructors. Five (5) sections were exposed to the proposed curation and structure described above (Group A), while the remaining five sections were only required to complete the same activities without access to the curation and structure described above (Group B, control). Both groups were required to complete 3 activities of their choice, and submit the same completion requirements. The instructors did not assign students to sections; they self-selected their sections when they registered for classes based on their schedules, which allowed for a natural, unbiased quasi-experimental design.

Group A received a structured educational implementation, which included a CFA schedule presented in both spreadsheet and Learning Management System (LMS) formats. A chronological spreadsheet of events, sign-up links, and CFA types was also provided (Figure 2). Additionally, Group A had access to the virtual versions of these activities to accommodate diversity in academic schedules.

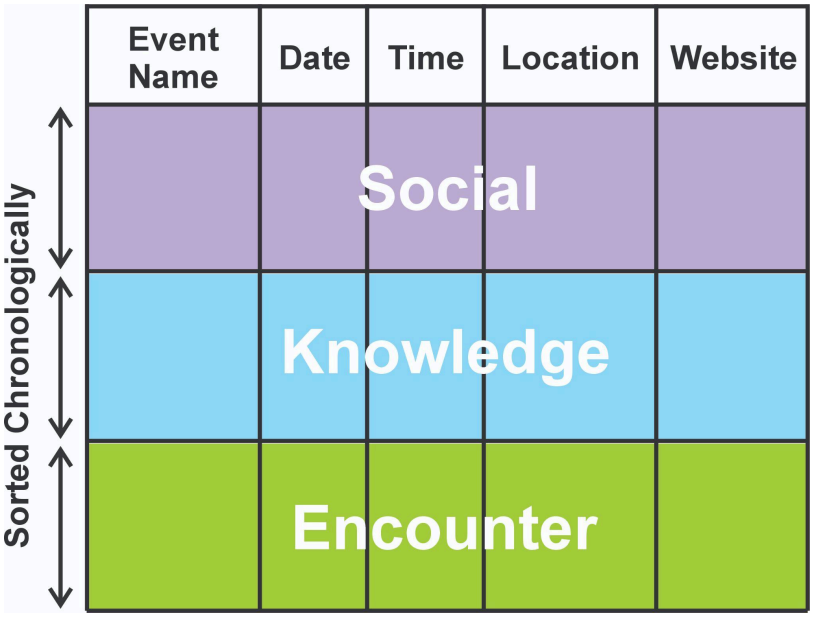

Figure 2. The spreadsheet for Group A was visually represented with the CFAs (Social, Knowledge, and Encounter) organized chronologically.

In contrast, Group B only had access to an unsorted spreadsheet of activities within the LMS. Group B, thus, did not receive any weekly reminders or LMS-posted information.

Group A & B students registered for the CFAs through Google Forms (the links were provided in the spreadsheet/LMS). Students were asked to provide information about their section, how they heard about the event, why they wanted to attend it, and any specific question(s) they hoped to get an answer to. Upon completing the form, they received a Google Calendar invite to confirm their registration.

After each event, students completed a reflection form to document their experiences and confirm their participation. The reflection form was standardized for all in-person CFAs. For the virtual CFAs, an additional section introducing and describing the activity was included (Fig. 3). This reflective process ensured students' thorough engagement, accountability, and thoughtful participation across all CFA formats, while highlighting their comprehension of the connection between CFAs, sustainability and academic development.

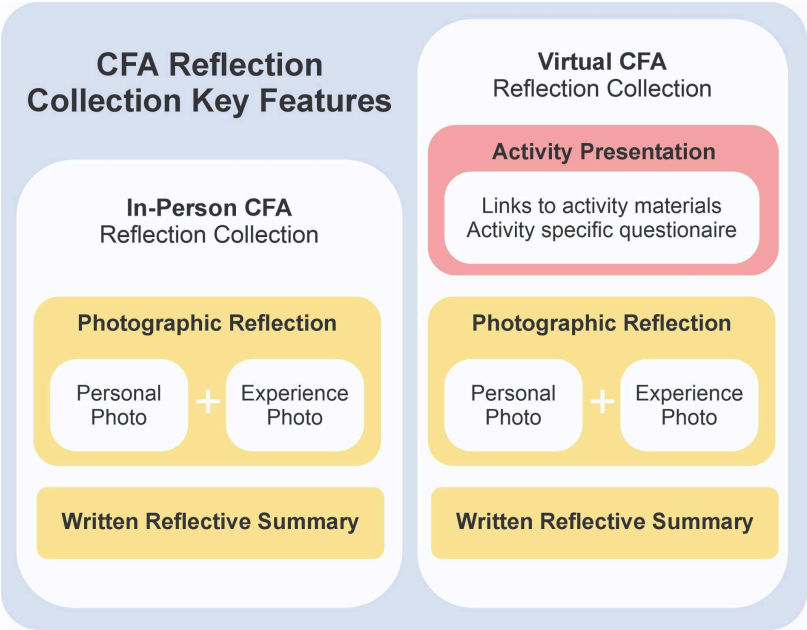

Figure 3. Reflection collection instruments for in-person *versus* virtual CFAs.

Data Collection

Qualitative and quantitative surveys were given to students in all sections (Group A and Group B) to assess their interest in sustainability across disciplines, interdisciplinary perspectives, and their knowledge of both campus sustainability efforts and the United Nations Sustainable Development Goals (UN SDGs). Because the UN SDGs framework is frequently introduced to define and support the concept of sustainability (both the concepts of sustainability and sustainable development are often used interchangeably), we included the UN SDGs in this study. However, as highlighted by recent research work [27], the UN SDGs framework does not fully encompass all aspects of sustainability. In this study, both concepts were discussed independently.

The pre- and post-course surveys were administered before the semester started and two weeks prior to the end of the semester, respectively. Pre- and post- course survey data was analyzed to assess evolution of students' knowledge and engagement in the following areas:

1. Comprehension of sustainability concepts resulting from exposure to the CFAs and classroom materials.
2. Participation in sustainability-related activities on campus resulting from the CFAs and classroom materials.
3. Student satisfaction with the CFA framework.

The post-course survey differed slightly for Groups A & B. Group B students (control group) were surveyed about their overall experience with the activities they completed. Group A students were surveyed on their educational experience and growth resulting from the CFAs. Group A data collection was conducted under the IRB protocol #27134.

Data processing

A total of 667 students responded to the surveys, out of which 40% (Group A: 41%; Group B: 40%) responded to the pre-course survey and 58% (Group A: 59%; Group B: 57%) to the post-course survey. The results were normalized to enable comparison between pre- and post-course survey results, and between the two groups.

Table 1. Overall responses for Group A and Group B

Population	Pre-course survey	Post-course survey
Group A	127 out of 312 students (41% response rate)	185 out of 312 students (59% response rate)
Group B	142 out of 355 students (40% response rate)	201 out of 355 students (57% response rate)

The survey questions can be found in Supplementary Information (Fig. S2).

Results and Discussion

The integration of curated activities like the CFAs into the curriculum of E102 aimed to raise students' awareness on the different facets of sustainability and their connections to engineering, while enhancing and boosting educational outcomes of engineering first-year students by providing a structured educational framework. Hence, our study aimed at assessing a series of hypotheses discussed hereinafter.

Hypothesis 1: The CFAs embedded in the Learning Management System (LMS) along with the asynchronous resources available to students will increase students' engagement and promptness for assignment completion.

Group A had access to the CFA framework, including email reminders, and the LMS. Group B had only access to the list of activities, without any reminders or LMS integration, as described in the implementation methodology.

The results show that the majority of the students were satisfied with their overall experience with 76% of Group A and 84% of Group B rating this experience with a 3 or more on the proposed likert-scale (5 being the highest value) (Fig. 4 a and b). This result demonstrates the benefits of offering a variety of learning experiences, topics and viewpoints for enhanced students' engagement.

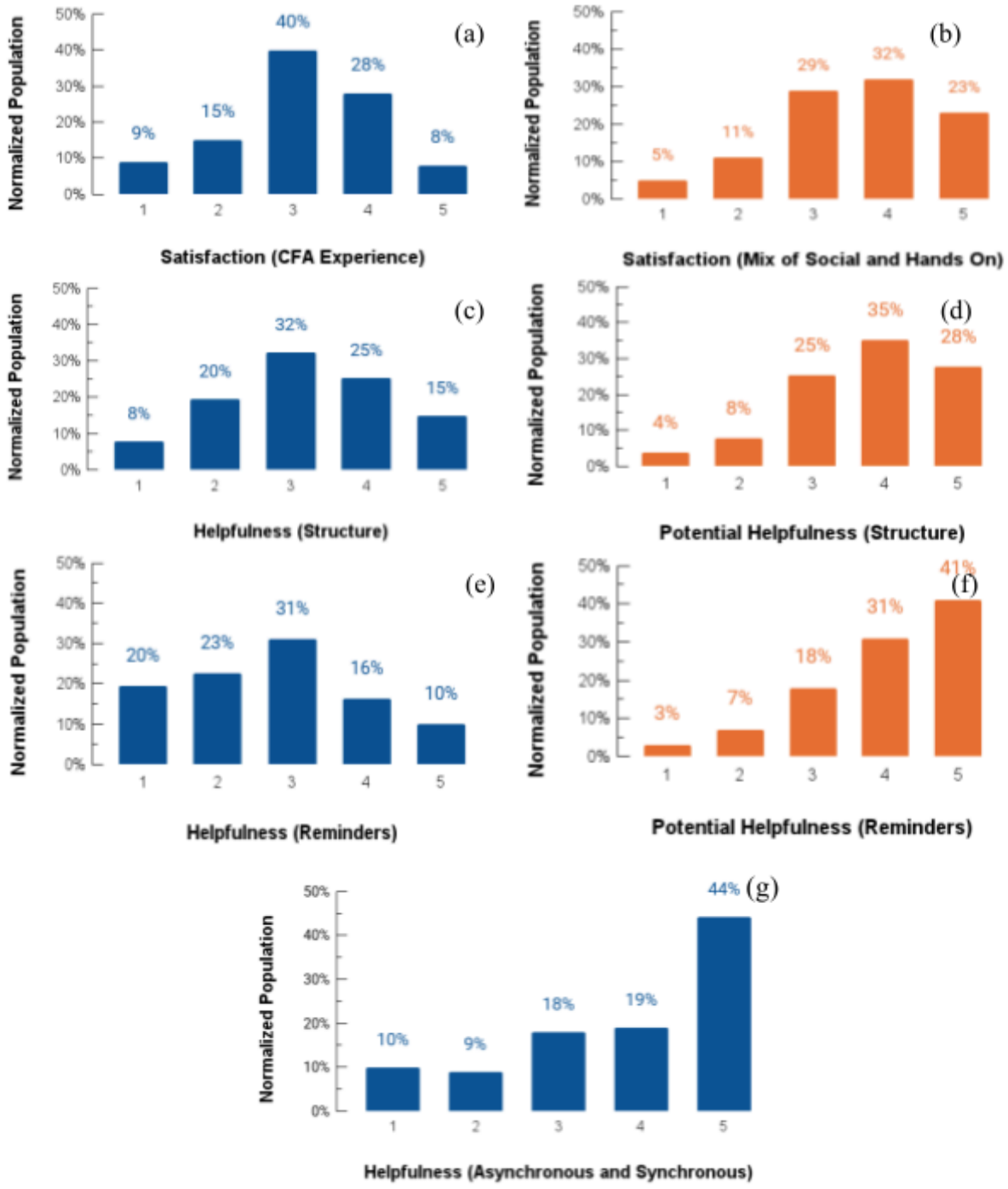

Figure 4. Results from post-course survey. (a) Group A's Satisfaction towards the CFAs, (b) Group B's Satisfaction towards their activities, (c) Group A's perception of helpfulness to scheduling, (d) Group B's perception of helpfulness of activity curation, (e) Group A's perception of the helpfulness for reminders, (f) Group B's perception of the usefulness for reminders, and (g) Group A's perception of helpfulness related to the provided flexibility (*i.e.*, hybrid format).

The presence of a structure to introduce the sustainability-related activities and help students navigate the diversity of the CFAs was, additionally, reported as highly beneficial. Group A, which had access to the structured CFA framework, confirmed the benefit of such an integrated format with 72% agreement (Figure 4d). In contrast, 88% of Group B, which did not have access to the structured CFA framework, overwhelmingly indicated that having one would have been helpful (Figure 4c). Hence, providing a structure to learning and a clear rationale such as the CFA educational framework, foster students' engagement, participation and achievements in sustainability-related HIEs.

While 57% of Group A participants reported that the Learning Management System (LMS) reminders were beneficial to their learning experience, a substantial majority of Group B participants (90%) indicated that they would have found such reminders helpful (Figures 4e-f). This discrepancy indicates that the LMS reminders were not determinant of the CFA framework's overall success. This thus suggests that the proposed structure of the CFA framework was clear enough and well-defined for students to navigate it and engage in the different proposed graded activities.

Another important component of the CFA framework relates to the flexibility provided by attending both synchronous and asynchronous activities. It is important to note that only Group A had access to both the synchronous and asynchronous activities, while Group B had only access to the synchronous activities. Access to this hybrid format was clearly reported as the most helpful tool, with 63% of Group A students rating it as a 4 or 5 in terms of helpfulness (Figure 4g). A total of 355 virtual Knowledge and Encounter CFAs completion forms were submitted for grading. The success of this hybrid format allowed students to engage with the course materials at their own pace, while completing in a timely manner their assignments. In fact, this structure has been shown to increase collaboration, curiosity, and positive attitudes of students toward the subject [9].

Hypothesis 2: Participation in Complementary Field Activities will increase students' sustainability-based practices on campus and beyond.

The creation of CFAs was rooted in the idea that engagement with campus resources like sustainability organizations fosters a sense of belonging and shared purpose, which has been associated with improved student achievements, well-being, and retention [16], [17]. To gauge the effectiveness of the CFA framework in enabling students to recognize sustainability practices on and off campus, the pre- and post-course surveys assessed their awareness of the UN SDGs and their ability to identify three campus sustainability resources (Fig. 5).

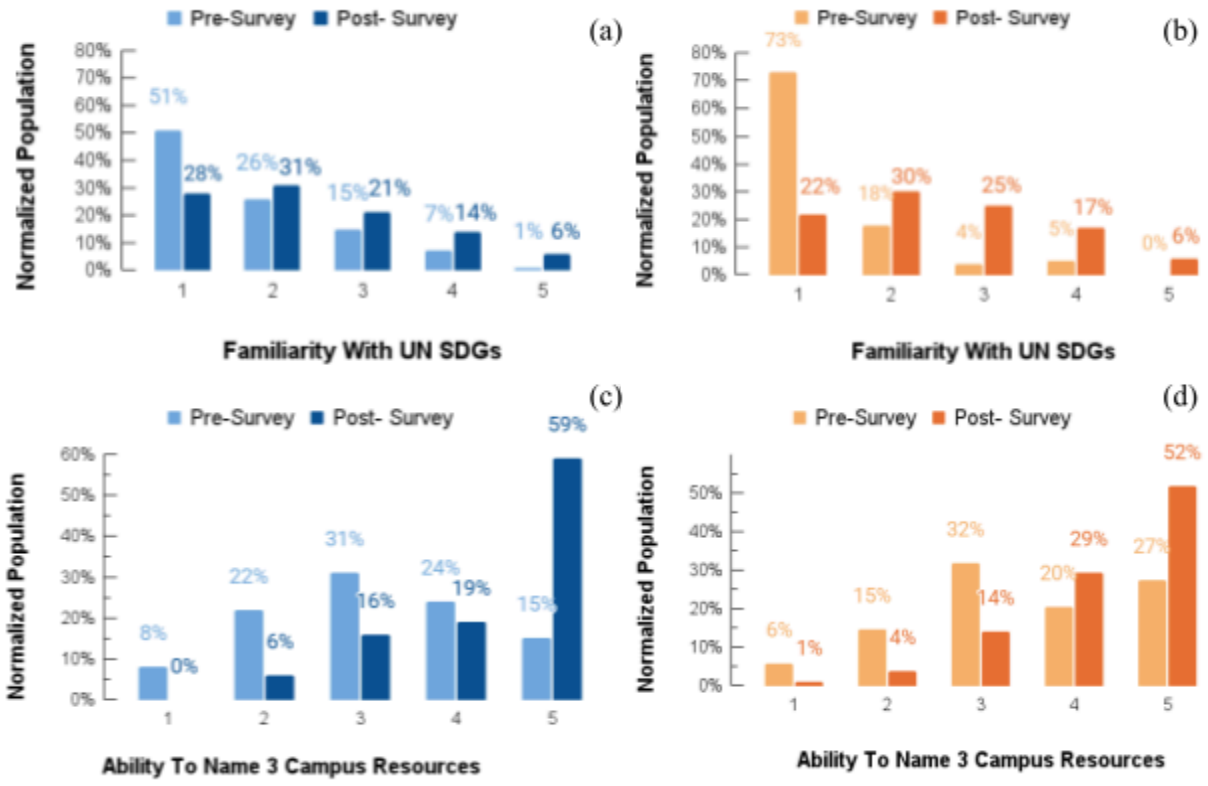

Figure 5. Familiarity with the UN SDGs of (a) Group A and (b) Group B. Ability of (c) Group A and (d) Group B to name three campus resources.

The surveys measuring familiarity with the UN SDGs before and after CFA participation revealed that, initially, most students were unfamiliar with these goals, with more than half of the surveyed students (in both Groups A and B) rating their familiarity level to the lowest rank, 1. At the end of the semester, only a third of the surveyed students remained strongly unfamiliar with the SDGs (Fig. 5a-b). Interestingly, the level of familiarity of students with the UN SDGs was similar for both Groups, although Group A had access to a more structured framework and more resources for developing their understanding of the SDGs. Hence, a future next step will be to explicitly include a CFA or more lecture content on the UN SDGs.

Regarding students' knowledge on campus sustainability resources, both Group A and Group B demonstrated increased ability to identify at least three resources after taking E102 (Figs. 5c-d). The confidence level of Group A students was yet slightly higher than that of the Group B students (a 44% *vs.* 25% increase of rank 5 votes, respectively), because Group A had higher exposure to campus sustainability resources through Social CFAs (campus events), Encounter CFAs (immersive on-campus and virtual facility visits), and Knowledge CFAs (hands-on learning with sustainability partners).

Hypothesis 3: The interdisciplinary nature of the CFAs will increase interests in research or internships (i.e., High Impact Experiences) and in sustainability.

The CFA framework encourages students to participate in HIEs through exposure to a diversity of networking opportunities and multi-disciplinary activities related to sustainability. Engagement in HIEs, such as internships or undergraduate research, can empower students to reflect about their journey, define professional and career goals and challenge their collaboration skills [14], [19]. This type of intentional learning builds confidence, networking skills and boosts student achievements [16], [17].

We evaluated the impact of the CFAs on the evolution of the interest level of students in participating in research. Figures 6 a-b show little variation in the students' responses prior to and at the end of the semester. Similar response trends are observed for both Groups A and B. A slightly higher interest level is yet seen for Group A students, who were exposed to the CFA framework (Fig. 6a). Yet, according to this data set, the proposed sustainability-related activities did not necessarily alter the motivation of undergraduate students to participate in research activities. Ultimately, their interest in research experience was already quite high prior to enrolling in E102, with >50% of the surveyed students ranking their interest level to a score of 3 and higher. Following the conclusion of the course, participants from both groups demonstrated a heightened awareness and concern for sustainability-related matters (Figure 6c). This heightened interest manifested itself in various ways, including but not limited to actively seeking out information on sustainable practices, expressing a desire to incorporate sustainability into their personal and professional lives, and engaging in discussions and debates surrounding sustainability issues.

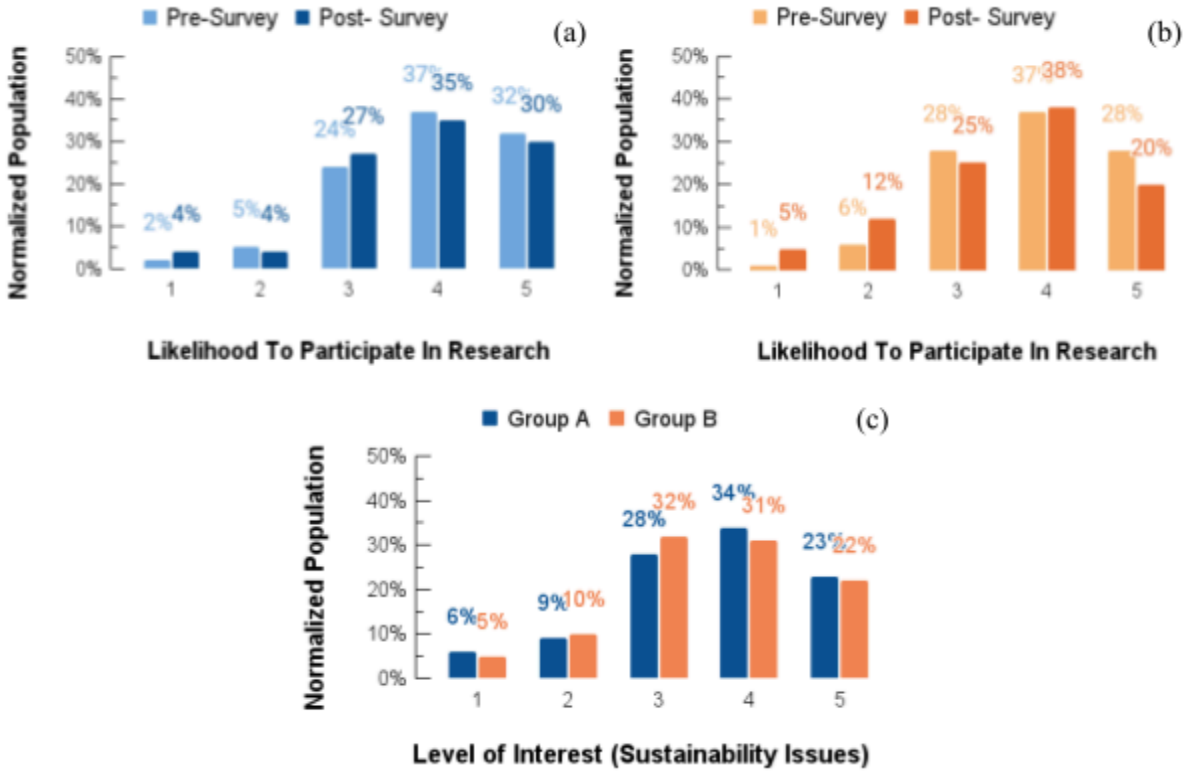

Figure 6. Interest level in research of (a) Group A and (b) Group B, and in (c) sustainability-related topics before and after enrolling in E102.

Conclusion

Implementation of the CFA framework promoted students' involvement in sustainability initiatives on campus, while fostering collaboration between campus partners, researchers, and sustainability practitioners. The curated HIEs in the CFAs demonstrated potential for enhancing students' engagement, encouraging sustainability awareness and embedding interdisciplinary learning into engineering education. The nature of the CFA learning module aimed to make activities more personalized to each student's learning experience and flexible enough to accommodate diverse schedules.

The structured framework was successful in introducing students to more campus resources relating to sustainability, especially those in Group A owing to the curated LMS. Familiarity with the UN SDGs did improve among students in both groups, but further data is required to draw conclusions on whether the CFA experiences solely contributed to the further understanding.

The provision of virtual encounter and knowledge CFAs to increase flexibility was shown to improve student satisfaction and enable personalization according to schedule and individual preferences. The CFA experience was found to be scalable and enjoyable for large student populations (over 700 students), suggesting further evaluation in larger cohorts and interdisciplinary engineering fields.

By connecting students to involvement in sustainability initiatives and networking opportunities, students are contributing to their career readiness. Introducing engineering students to sustainability issues is crucial, as it fosters collaboration skills and equips them to address this significant engineering grand challenge, promoting advancements in their respective fields. This model can be adopted for any of the other grand challenges or related topics to increase students' engagement and interdisciplinary learning in engineering education.

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Resources

A "Card" – i.e., an information repository – has been created for this paper on the Engineering Unleashed website. [30] TThe instructional materials provided here, including sign-up forms, presentation outlines, and templates, are available for free download under the Creative Commons CC BY-NC license. These resources can be reviewed, adopted, and modified as needed for use in courses and programs. [31]

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Supplemental information: **Integrating Sustainability into Engineering Education: The Impact of Complementary Field Activities on Student Engagement**

Additional Figures

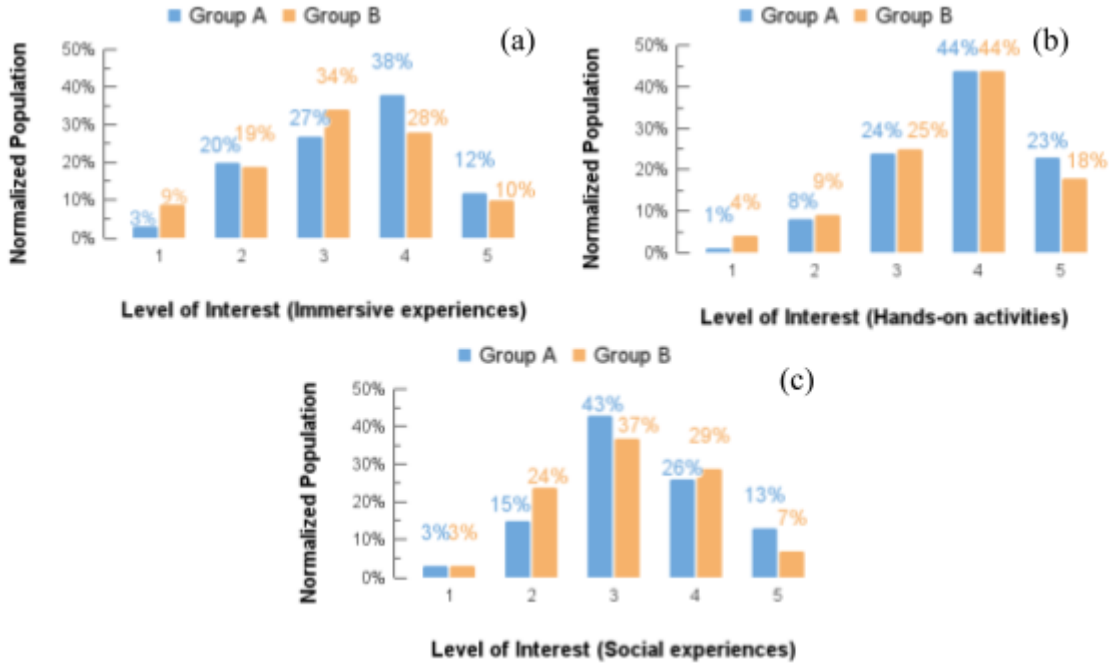

Figure SI1. Results from pre-survey questions related to (a) Group A and B's level of interest in immersive experiences, (b) Group A and B's level of interest in hands on activities (c) Group A and B's level of interest in social experiences

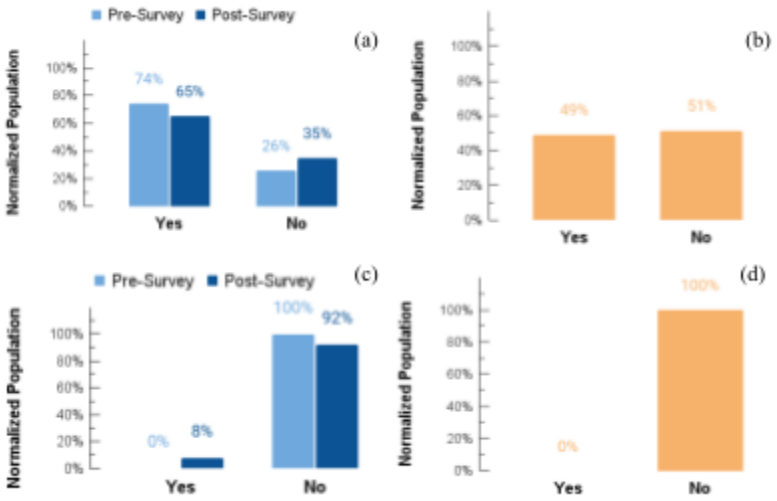

Figure SI2. Interest in joining an organization related to sustainability for (a) Group A pre-survey and post survey (b) Group B pre- survey, and membership in a sustainability organization for (c) Group A pre- survey and post survey and (d) Group B pre- survey

Pre- Survey Questionnaire

Screening questions

1. Are you 18 years of age or older?
2. Do you reside in the US?
3. Are you enrolled in E102 currently?
4. If any of the answers is no, they will be excluded from the survey.

Consent form

You are being asked to complete a survey for research purposes. The survey is aimed at measuring student perceptions of E102 writing and major exploration activities, as well as how student involvement in the course influences a sustainability mindset in Engineering. The survey will take you approximately 10-15 minutes to complete.

You must be 18 years of age or older, reside in the United States, and be an actively enrolled E102 student in the Fall 2024 to participate in this study.

For this study, you will rate your level of agreement with several statements and answer several questions. Your individual responses will remain anonymous through a random identifier that will not be shared with the researchers until after the end of the academic semester. Completing this survey is voluntary. At any point during this survey, you can decide to participate, to not participate, or to stop participating. To stop participating, exit out of the survey.

We suggest that you take this survey using a private device, in a private location, using a web browser set to private/incognito mode. The data collected about you from this survey will be stored in accordance with NC State data protection standards.

Due to our role as academic advisors in the College of Engineering, we have an obligation to report any unlawful and suspicious behavior. we have an obligation to report child neglect and abuse, sexual abuse of an adult ages 28 years old or younger, elder neglect and abuse, sexual discrimination and harassment of students, etc. This means that if we observe instances of, or you tell me about unlawful or suspicious behavior, we are obligated to report that.
There are minimal risks for participating. Your responses may be used to improve future programming, and will be included in presentations and publications on the results of this research project.

You will receive no payment for completing this survey.

If you consent to participate in the survey, please press the next button below.

Survey Block 1: Demographics

1. The following questions will help us generate a Random ID Number for your response. This number and letter combination will be used again at the end of the course in a post-course survey.
    a. First letter of your first name
    b. Enter the day of the month in which your birthday falls (e.g., 1, 15, 30)
    c. First letter of middle name (if none, use 'X')
    d. First letter of city/town you were born in
2. What section of E102 are you taking? (dropdown list)
3. Which of the following best defines your current gender identity? Select all that apply
    a. Genderqueer, nonbinary, or genderfluid
    b. Man
    c. Woman
    d. Prefer to self-describe _____
    e. Prefer not to respond
4. Which of the following best defines your race or ethnicity? Select all that apply:
    a. American Indian or Alaska Native
    b. Asian
    c. Black or African American
    d. Hispanic, Latino/a/é, or Spanish
    e. Middle Eastern or North African
    f. Native Hawaiian or Other Pacific Islander
    g. White
    h. Prefer to self-describe _____
    i. Prefer not to respond
5. Do you identify with having or living with a disability?
    a. Yes

b. No
c. Prefer not to respond

Survey Block 2: General Questions on Undergraduate Research

6. I have a strong understanding of Engineering's Grand Challenges. (1-5 slider scale)
7. How interested are you in conducting research? (1-5 slider scale)
    a. *(if a 4 or 5)* What three factors do you think have influenced your decision on pursuing undergraduate research? (open ended text)
8. How likely are you to consider participating in research activities if you are given the chance? (1-5 slider scale)
9. I can conduct scholarly research on a topic. (1-5 slider scale)
10. I can explain research findings in my own words. (1-5 slider scale)
11. I can cite references appropriately in my research. (1-5 slider scale)
12. I work well in project teams.
13. I am comfortable taking feedback on my work from my peers. (1-5 slider scale)
14. I am confident that I can name three campus resources that are available for me (1-5 slider scale)
15. I know what it means to be interdisciplinary. (1-5 slider scale)

Survey Block 2: Writing Assignment

16. Rate the impact that you believe your course writing assignments will have outside the classroom (e.g. in other courses, in professional life). (1-5 slider scale)
17. How useful do you think using AI based tools are to assist you in writing. (1-5 slider scale)
18. How confident are you in your ability to use AI based tools to assist you writing scientific related documents? (1-5 slider scale)
19. Have you contributed to an educational open access resource related to science and engineering? (yes/no)
20. *(if yes)* I plan to contribute to open access research consistently in the future. (5 pt. Likert Scale – Strongly Disagree to Strongly Agree)
21. *(if no)* Why not? (open ended text)
22. I would be interested in contributing to an open access resource related to science and engineering. (1-5 slider scale)

Survey Block 3: Major Exploration

The following questions will ask you about exploring different majors in Engineering.

23. Have you chosen which Engineering discipline you would like to pursue yet? (yes/maybe-unsure/no)
24. I anticipate that hearing from graduate students and other professionals in different Engineering disciplines will have an impact on my decision (5 pt. Likert Scale – Strongly Disagree to Strongly Agree)
25. What engineering major(s) interest you the most currently? (Select all that apply)

a. Aerospace Engineering (AE)
b. Biological Engineering (BAE)
c. Biomedical Engineering (BME)
d. Chemical Engineering (CHE)
e. Civil Engineering (CE)
f. Computer Engineering (CPE)
g. Computer Science (CSC)
h. Construction Engineering (CON)
i. Electrical Engineering (EE)
j. Environmental Engineering (ENE)
k. Industrial Engineering (ISE)
l. Materials Science and Engineering (MSE)
m. Mechanical Engineering (ME)
n. Nuclear Engineering (NE)
o. Paper Science and Engineering (PSE)
p. Textile Engineering (TE)
q. Unsure

26. How knowledgeable do you feel about how the different majors contribute to solving the grand challenges of engineering? (1-5 slider scale)
27. What three words come in mind when you think about what influenced your decision on pursuing an engineering major? (open ended text)

Survey Block 4: Complementary Field Activities –

28. How familiar are you with the United Nations (UN) Sustainability Development Goal (SDG)? (1-5 slider scale)
29. Rate your level of interest that you have regarding hands-on experiences in Engineering sustainability topics. (1-5 slider scale)
30. Rate your level of interest that you have regarding immersive in-person or asynchronous virtual reality experiences in sustainability and circularity topics. (1-5 slider scale)
31. Rate the level of interest that you have regarding social experiences related to sustainability on campus (1-5 slider scale) (If 4-5 ->33)
32. Have you considered joining a club related to sustainability on campus? (yes/no)
    a. (if yes) Have you already joined a club related to sustainability on campus? (yes/no)
    b. *(If yes)* Which one(s)? (open ended text)

Post- Survey Questionnaire:

Screening questions

5. Are you 18 years of age or older?
6. Do you reside in the US?
7. Are you enrolled in E102 currently?
8. If any of the answers is no, they will be excluded from the survey.

Survey Block 1: Random Identifier

1. The following questions will help us generate a Random ID Number for your response. This number and letter combination will be used again at the end of the course in a post-course survey.
    a. First letter of your first name
    b. Enter the day of the month in which your birthday falls (e.g., 1, 15, 30)
    c. First letter of middle name (if none, use 'X')
    d. First letter of city/town you were born in
2. What section of E102 are you taking? (dropdown list)

Survey Block 2: General Questions on Undergraduate Research

The following questions will ask you to rank your level of agreement with the statements provided.

3. I have a strong understanding of Engineering's Grand Challenges. (1-5 slider scale)
4. How interested are you in conducting research? (1-5 slider scale)
    a. *(if a 4 or 5)* What three factors do you think have influenced your decision on pursuing undergraduate research? (open ended text)
5. How likely are you to consider participating in research activities if you are given the chance? (1-5 slider scale)
6. I can conduct scholarly research on a topic. (1-5 slider scale)
7. I can explain research findings in my own words. (1-5 slider scale)
8. I can cite references appropriately in my research. (1-5 slider scale)
9. I work well in project teams.
10. I am comfortable taking feedback on my work from my peers. (1-5 slider scale)
11. I am confident that I can name three campus resources that are available for me (1-5 slider scale)
12. I know what it means to be interdisciplinary. (1-5 slider scale)

Survey Block 2: Writing Assignment

13. Rate the impact that you believe your course writing assignments will have outside the classroom (e.g. in other courses, in professional life). (1-5 slider scale)
14. Have you contributed to an educational open access resource related to science and engineering?
    a. (if yes) I plan to contribute to open access research consistently in the future. (1-5 scale level of agreement)
    b. (if no) Why not? (text entry)
15. *Survey Display Logic - if E102 section chosen in Q2 that is denoted as Group A these questions are displayed:*
    a. I enjoyed that an open access contribution was part of the course structure (1-5 slider scale)
    b. How helpful was it to integrate AI based tools to assist you with your writing? (1-5 slider scale)

    c. How confident are you in your ability to use AI based tools to assist you in writing scientific related documents? (1-5 slider scale)

16. *Survey Display Logic - if E102 section chosen in Q2 that is denoted as Group B, these questions are displayed:*
    a. I would have enjoyed having open access contributions to science and engineering as a part of the course (1-5 scale level of agreement)
    b. I would have enjoyed it if AI based tools were introduced as an assistant for writing assignments. (1-5 scale level of agreement)
    c. What would you suggest to be used as the writing assignment?

Survey Block 3: Major Exploration

The following questions will ask you about exploring different majors in Engineering.

17. Have you chosen which Engineering discipline you would like to pursue yet?
    a. Yes
    b. No
18. The class activities we did throughout the semester helped me decide what major to pursue (1-5 level of agreement)
19. Hearing from graduate students and other professionals in different Engineering disciplines had an impact on my decision (1-5 level of agreement)
20. What engineering major(s) interest you the most currently? (Select all that apply)
    a. Aerospace Engineering (AE)
    b. Biological Engineering (BE)
    c. Biomedical Engineering (BME)
    d. Chemical Engineering (CHE)
    e. Civil Engineering (CE)
    f. Computer Engineering (CPE)
    g. Computer Science (CSC)
    h. Construction Engineering (CON)
    i. Electrical Engineering (EE)
    j. Environmental Engineering (ENE)
    k. Industrial Engineering (IE)
    l. Materials Science and Engineering (MSE)
    m. Mechanical Engineering (ME)
    n. Nuclear Engineering (NE)
    o. Paper Science and Engineering (PSE)
    p. Textile Engineering (TE)
    q. Unsure
21. How knowledgeable do you feel about how the different engineering majors contribute to solving the grand challenges of engineering? (1-5 slider scale)
22. In three distinct words, what factors do you think have influenced your decision on pursuing an engineering major? (open ended text)

Survey Block 4: Complementary Field Activities –

23. How familiar are you with the United Nations Sustainability Development Goal (SDG)? (1-5 slider scale)
24. Rate your level of interest that you have regarding sustainability issues. (1-5 slider scale)
25. *Survey Display Logic - if E102 section chosen in Q2 that is denoted as Group A these questions are displayed:*
    a. What types of complementary field activities did you participate in this semester? (Select all that apply)
        i. Social
        ii. Knowledge
        iii. Encounter
    b. What was your overall satisfaction with the complementary field activities you participated in? (1-5 slider scale)
    c. How helpful were the follow aspects of curated complementary field activities. (1-5 slider scale)
        i. Scheduling
        ii. Reminders
        iii. Moodle access
        iv. Variety of activities
        v. Synchronous and asynchronous options
    d. Rate your level of interest that you have regarding social experiences in sustainability topics. (1-5 slider scale)
        i. (*if 4 or 5 answered above*) Have you considered joining a club related to sustainability on campus? (Yes/No)
            1. (*if yes*) Have you already joined a club related to sustainability on campus? (Yes/No)
                a. *(if yes)* Which ones? (open ended text)
26. *Survey Display Logic - if E102 section chosen in Q2 that is denoted as Group B, these questions are displayed:*
    a. It would have been helpful to have a list of curated activities provided to me in an organized spreadsheet. (1-5 scale level of agreement)
    b. It would have been helpful to have a list of curated activities organized for me in Moodle. (1-5 scale level of agreement)
    c. It would have been helpful to have had reminders about the activities and deadlines. (1-5 scale level of agreement)
    d. I would have liked to have had a better mix of hands-on and social activities related to sustainability. (1-5 scale level of agreement)