ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37954

Sustainability Inclusion Efforts in Three Unique First-Year Engineering Courses

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Abstract

Throughout the world, various institutions and programs are working to integrate sustainability into engineering education. University engineering programs can be a pivotal place for future engineers to gain understanding of sustainability and its importance, including in first-year courses. At the University of Colorado Boulder, three courses for first year engineering students are uniquely integrating sustainability. The courses selected for this study are 1) First-Year Engineering Projects, 2) Introduction to Civil Engineering, and 3) Introduction to Global Engineering. *First-Year Engineering Projects* provides students with the opportunity to use an iterative process to solve real engineering design problems. *Introduction to Civil Engineering* surveys the discipline and incorporates learning goals on ethics and sustainability. *Introduction to Global Engineering* addresses the engineer's role in identifying and acting on global poverty challenges. In this paper, we describe the explicit and implicit learning goals with respect to sustainability in these courses. We then map the sustainability content to the three pillars of sustainability, the 17 UN Sustainable Development Goals, and Bloom's Taxonomy of Cognitive Levels. At the end of the Fall 2021 semester, students in each of the three courses were asked to complete a survey that used 7-pt Likert-type items to evaluate student interest and motivation toward sustainability and 11-point rating items on confidence/self-efficacy. Student perception on sustainability was found to differ by: course, discipline, gender, major, student previous knowledge, and student general interests. Within each course, impactful factors include the learning objectives, quantity of sustainability inclusion and method of delivery. A given course is not the sole determining factor of students' awareness of sustainability, but it can have an effect. Sustainability can look different across engineering disciplines, and each area and method of incorporating sustainability has its own place, value, and impact.

Introduction and Background

> *"Development can be considered sustainable if it allows every people globally to at least meet their basic needs, if it provides individuals in a given society equal opportunities to increase their quality of life, and if it provides future generations increasing opportunities."* [1]

Sustainability, defined as such, is a component in each of the first-year engineering courses studied in this paper. The first year of college is especially impactful in that students are beginning to form their professional identities. "The freshman year is the time to create expectations and habits as well as interdisciplinary cognitive skills and course-specific knowledge" [2]. Thus, with the goal to successfully integrate sustainability into a student's sense of self as an engineer, it is potentially more effective to include sustainability in their first-year curricula, than if sustainability remained later in their university experiences [2] .

There are a variety of impactful sustainability incorporation methods and contexts for achieving an array of cognitive and/or affective sustainability related outcomes. Sustainability related learning objectives and outcomes do not need to be solely limited to sustainability focused courses. Integration of sustainability concepts into existing and traditional engineering courses gives students a broad understanding of the field and prepares them to apply sustainability related principles in their engineering decisions. Thus, including sustainability principles throughout an engineer's studies at the university-level can provide greater depth and understanding of the desired learning outcomes [3].

The engineering courses of interest for this study are: First Year Engineering Projects (FYEP), Introduction to Civil Engineering, and Introduction to Global Engineering. Based on American Association for Sustainability in Higher Education STARS data, out of 50 large engineering universities selected for the study in Tisdale & Bielefeldt 2021 [4], 16 universities have included sustainability in an introductory course for civil and/or environmental engineering, seven in an introductory design/projects course and three in a global engineering course. Note that STARS is traditionally utilized for universities to chart their campus wide sustainability efforts. This includes sustainability in course curricula, and it can also be used for institutions to map their contributions to the UN Sustainable Development Goals (SDGs) [5]. The SDGs are summarized in Table 1. AASHE provides an academic course inventory template to assist in mapping courses to the SDGs [5]. The University College Cork, the University of Richmond, and Champlain College were highlighted as early adopters of mapping their courses to the SDGs [5]. However, SDG mapping in the curriculum does not yet appear common.

Table 1. UN SDGs [6]

1. No poverty	7. Affordable and clean energy	13. Climate action
2. Zero hunger	8. Decent work and economic growth	14. Life below water
3. Good health and well-being	9. Industry, innovation and infrastructure	15. Life on land
4. Quality education	10. Reduced inequalities	16. Peace, justice and strong institutions
5. Gender equality	11. Sustainable cities and communities	17. Partnerships for the goals
6. Clean water and sanitation	12. Responsible consumption and production	

In a broader context, it has been argued that all engineers should design for sustainability, as indicated by inclusion in the International Engineering Alliance outcomes [7]. However, only some of the engineering professional society codes of ethics in the U.S. explicitly include sustainability [8]. The American Society of Civil Engineers (ASCE) believes that all engineers should have knowledge, skills, and attitudes related to sustainable engineering; the outcomes have been mapped to Bloom's taxonomy as shown in Table 2. Further, research has found differences in the extent that faculty in different disciplines integrate sustainability topics into their courses [8] [9] [10] [11].

Table 2. ASCE BOK3 Sustainability Outcome [typical pathway; UG = undergraduate education; MExp = mentored experience] [11]

Cognitive Domain Level of Achievement	Ability	Affective Domain Level of Achievement	
1. Remember	Identify concepts and principles of sustainability. [UG]	1. Receive	Acknowledge the importance of sustainability in civil engineering. [UG]
2. Comprehend	Explain concepts and principles of sustainability. [UG]	2. Respond	Comply with the concepts and principles of sustainability in civil engineering. [UG]
3. Apply	Apply concepts and principles of sustainability to the solution of complex civil engineering problems. [UG]	3. Value	Value the benefits of sustainability in the practice of civil engineering. [MExp]
4. Analyze	Analyze the sustainable performance of complex civil engineering projects from a systems perspective. [MExp]	4. Organize	Integrate a commitment to sustainability principles into the practice of civil engineering. [Self-developed]

This study contributes to the literature by documenting how sustainability is integrated into three unique courses for first-year engineering students, and then beginning to examine students' attitudes with respect to sustainability and/or sustainable engineering. Specifically, this research explored the following questions:

- How do three courses for first-year engineering students incorporate the UN Sustainable Development Goals? How does the course content related to sustainable engineering in these courses map to Bloom's Taxonomy?
- Are there differences in the sustainability attitudes (interest, self-efficacy) among students at the end of these three courses with sustainability inclusion? To what extent do these differences appear related to the majors of the students and/or gender?
- What connections can be drawn between sustainability inclusion in the course and the students' attitudes about sustainability?

Descriptions of Courses

The instructors of three courses targeted for first-year engineering students at the University of Colorado Boulder (CU) participated in this Scholarship of Teaching and Learning exercise together. CU is a large, public institution that offers ABET EAC accredited degrees in a number of different engineering majors. The three courses included in the study are: First-Year

Engineering Projects (FYEP); Introduction to Civil Engineering (IntroCivE), and Introduction to Global Engineering (GlobalE). These courses each represent unique and different contexts and learning objectives. Table 3 provides an overview of these courses; syllabi excerpts are provided in Appendix B.

Table 3: Course Overviews

	First-Year Engineering Projects (FYEP)	Introduction to Global Engineering (GlobalE)	Introduction to Civil Engineering (IntroCivE)
Credits	3	3	1
Context	Required for most engineering majors	Required for students in a residential academic program or pursuing a global engineering minor	Required for students majoring in civil engineering
Primary Learning Objectives	Design, teamwork, communication, eng methods, eng ethics	Design for sustainable global development, teamwork, communication, social justice, ethics	Knowledge of discipline, ethics, sustainability
Course configuration in Fall 2021	12 sections, ~30 students each, 11 instructors [3 instructors participated in the study]	2 sections, ~60 students each	1 section, ~32 students
Sustainability inclusion	Varied across sections	SDG principles interwoven throughout the course and the focus of design challenge project	1 of 6 learning objectives; 1 small assignment and integrated into ethics and design

The sustainability-related content of each of the three courses, and the sections of FYEP that participated in the study are summarized below.

Introduction to Global Engineering (GlobalE)
GlobalE is a three-credit course that is cross-listed at the 2000-level and 4000-level, with the former targeted at students who live in a first-year residential academic program (RAP) focused on Global Engineering and the latter serving as an elective for upper-level students. Both offerings meet a core requirement of the Global Engineering Minor. There were two sections of the course in Fall 2021, each with an enrollment of approximately 60 students. Approximately 90% of the students in the course were first-year students enrolled as a requirement for the RAP; not all first-year students were members of the RAP.

The course was team-taught by four individuals, including the third and fourth authors of this paper. GlobalE does not have specific learning objectives that relate to sustainability in an intergenerational sense. Rather, the course focuses on social issues (including geopolitical and historical contexts of health and socioeconomic disparities within and between countries) and technical interventions that address water, sanitation, hygiene, energy, infrastructure, shelter, and agricultural needs (linked to the UN SDGs). One could characterize the course as focusing on intra-generational equity and improved well-being, rather than the more traditional focus of sustainability on intergenerational equity and environmental issues.

The required textbook for the course is "The Divide" by Jason Hickel [12], which argues that persistent poverty is a political and economic phenomenon, as opposed to a natural one caused by climatic, geographic, and cultural forces. This book is supplemented by sections of Evan Thomas' book "The Global Engineers" [13] and other lecture-specific materials.

The course integrates a semester-long group design project based on the Engineering for People Design Challenge, an Engineering Without Borders UK initiative that encourages participants to broaden their awareness of the social, environmental, and economic implications of their engineering solutions. Since 2011, the Design Challenge has been delivered in South Africa, UK, Ireland, and the USA, to over 50,000 students, mostly in the first year of their engineering studies [14]. The initiative contributes to the UK Engineering Council requirements for students on accredited degrees to demonstrate understanding of the design process and have a broad awareness of the economic, legal, social, ethical, and environmental context of engineering [15].

The learning objectives of the Design Challenge include:

- Explore the different phases in the iterative process of engineering design;
- Create innovative technological solutions for underserved communities;
- Gain an understanding of their role in the engineering community;
- Learn to consider the consequences of design decisions at both local and global levels;
- Learn how engineering underpins everyday life;
- Learn how to place people at the heart of their designs; and
- Develop skills in engineering, communication, planning and project management, effective distribution of work and collaboration.

In Fall of 2021, the project was focused on a real-world scenario in the Cape York Peninsula in Australia. Students were provided with a Design Brief, which included extensive information about the national and local context and described problems that the Aboriginal and Torres Strait Islander population faces. These problems were grouped in the following challenge areas, which were related to several SDGs: water (SDGs 6, 7, 17), sanitation (SDGs 5, 6, 17), energy (SDGs 6, 7, 2), food and land management (SDGs 13, 14, 15), the built environment (SDGs 3, 9, 11), transportation (SDGs 3, 9, 11), waste management (SDGs 12,13,17), and digital (SDGs 8, 11, 17). The proposed solution needed to respond to one or more of these challenges and needed to also be related to at least one of the 50 Breakthroughs published by the Institute for Transformative Technologies, with the latter requirement added specifically for the GlobalE course. These breakthroughs were defined as the most important science and technology innovations needed to achieve the SDGs, and they have been adopted by the UN Commission on Science and Technology for Development as a technology roadmap [16].

The students were asked to navigate the different stages of the engineering design process and to deliver multiple presentations (project selection, preliminary design review, critical design review) during which they received feedback from the instructors and their classmates. Criteria for the assessment of the projects included: appreciation and consideration of the social, environmental, and economic context (which, combined, speak to the sustainability of the proposed solution); a methodical assessment process to select a preferred design by comparing options against specific criteria; consideration of design implementation and predicted difficulties; and evidence of reflection and critical thinking.

Introduction to Civil Engineering (IntroCivE)

This was a 1-credit course intended to introduce first year students to the profession of civil engineering. The syllabus articulated five learning goals, including 'define sustainability and describe its importance to civil engineering'. Another learning objective related to ethics, and sustainability is prominent within the American Society of Civil Engineers (ASCE) code of ethics. The course primarily used a flipped learning style where students were assigned a short reading passage or video and then asked to complete a short weekly assignment (300-500 word write-up) prior to discussing the topic during class. Sustainable engineering and ethics were two among the 12 weekly assignments and discussions, which included content from Royal Academy of Engineering and ASEE Community Pane [17] [18]. In addition, the course included a larger team project to design a bridge. The bridges were judged based on cost, environmental impacts, and social impacts (bringing in elements of sustainability). The teams were also required to discuss three of the point categories under the Envision rating system [19] that they would plan for their bridge to earn. Envision focuses on the environmental and social pillars of sustainability. Furthermore, in the final reflective essay for the semester, students were prompted to consider the following: "Discuss why ethics and sustainability are important to civil engineering" and "How do ethics and sustainability relate to your future career goals?" Thus, sustainability was introduced in the course and reinforced.

Although the SDGs were not explicitly discussed, content in the course related somewhat to: SDG 3 Good Health and Wellbeing (health impacts of civil engineering infrastructure and wellbeing requirement in the Code of Ethics), SDG 6 Clean Water and Sanitation (focus areas of civil engineering, ASCE Infrastructure Report Card for these areas), SDG 9 Infrastructure (focus of civil engineering), SDG 10 Reduced Inequalities (equity topic during one week including weekly assignment), and SDG 11 Sustainable Cities and Communities (related to civil engineering).

Bloom's taxonomy from the ASCE BOK [11] was used to form the learning goals for the course, which were aimed at level 1 (to remember) and 2 (to comprehend) with some movement into level 3 (to apply) via the mini team-based design project. However, some teams 'divided' the work with only one or two students completing the sustainability portion versus the entire group discussing those elements together. In the affective domain, the instructor had a strong focus on level 1, so that students would 'acknowledge the importance of sustainability in civil engineering.' This was used to form a foundation that would hopefully build to level 2 and level 3 (value the benefits of sustainability in the practice of civil engineering). Lectures often talked about resilience and the long-term nature of infrastructure, so hopefully students could appreciate taking a long-term view of environmental, social, and economic elements.

First-Year Engineering Projects (FYEP)
The learning objectives for all sections of FYEP include open-ended hands-on design experience, teamwork skills, communication skills, engineering methodology, and engineering ethics. Students learn in a hands-on way valuable engineering skills including communication skills, how to function in teams, and a variety of computer tools, such as programming microcontrollers, computer-aided design (CAD) and electronics. Students in any engineering major can enroll in the course, with each section typically including a maximum of 30 students. Beyond these learning objectives, each instructor has freedom and flexibility to include other topics of interest, such as sustainability. The way sustainability is included in the multiple sections is variable and depends on the instructor. Four sections of FYEP taught by three different instructors (of the 12 FYEP sections taught in Fall 2021) were included in this study. These have been distinguished in this paper as FYEP-1, FYEP-2 and FYEP-3.

FYEP-1
Two sections of FYEP were taught by the same instructor, who was invited to participate in the study based on sustainability integration; the instructor was interviewed to ascertain their teaching practices. Student teams were given an introductory project of creating a billboard with a social mission. Subsequently, the class hosted a guest speaker with a focus on climate change. This guest speaker also discussed an organization he started that brings together donors for the purpose of empowering university students to work on climate change solutions. In the main design project for this section, students were tasked with applying science, technology, and engineering to solve carbon pollution problems and communicating this in a way that can change people's behavior. Students were then given specific prompts from which to design their final projects.

Based on this sustainability inclusion, the students had exposure to the social and environmental sustainability pillars in both the guest speakers' lecture and in the introductory and main project assignments. The sustainable development goal number 13 for climate action was a high focus in the course as this was the primary focus of their main design projects. The prompts for possible foci of the main projects included topics from the following sustainable development goals: 7 (Affordable and Clean Energy), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), 16 (Peace, Justice and Strong Institutions) and 17 (Partnerships for the Goals).

In regard to the cognitive outcomes, students were tasked with 'remembering' and 'comprehending' the guest lecture, 'applying' the lecture and then 'creating' with their design projects.

FYEP-2
In the section of FYEP taught by the first author, the primary design project was given the theme of 'Sustainable Futures'. Students were asked to envision a more sustainable life thirty years from now. From this vision, they were tasked with designing and building a product that would be a part of the more sustainable future. The students were not given further prompts. The projects selected by the students were primarily within SDG 12 Responsible Consumption and Production and SDG 7 Affordable and Clean Energy.

In a sustainability focused lecture, the students were given the definition of sustainability as 'meeting the needs of today, without taking away future generations ability to meet their needs.' Within the lecture, there was articulation on both the inter and intra generational aspects of sustainability. The lecture included an introduction to the three pillars of sustainability, environmental, economic, and social. Additionally, the UN's 17 Sustainable Development Goals were presented and discussed. Lastly, there was a video focused on sustainable design for engineers.

The cognitive outcomes were quite similar to the FYEP-1 section, as students were required: 'to remember', 'to comprehend' the sustainability focused lecture as well as 'to apply' and 'to create' in their primary design projects.

FYEP-3

In the section of FYEP taught by the second author, student teams were given an introductory project of creating a light sculpture to promote awareness of a cause; two of the six teams opted to focus on sustainability related topics. For the primary design projects, student teams were given full autonomy in selecting a project of interest. To generate ideas, students were presented with the broad topic areas:

- Jump Into STEM challenge areas of equal access to healthy indoor air, resilience in the wake of disaster, and market adoption for emerging efficiency technologies [20]
- The climate action focus used in FYEP-1 section
- The WERC challenge (carbon conversion for the energy transition [21]
- Sensors

Two teams selected projects that related to SDG 13 'Climate Action'.

There was little to no direct discussion of sustainability in this section. Toward the beginning of the course, students were presented with the definition of design from ABET, which states that examples of possible constraints include 'sustainability', among other factors [22]. Subsequently, sustainability was included among the list of skills that students may have. Beyond that, the course used a human centered design model [8], thus emphasizing social elements in design. The design process was also shown as embedded within the complex system of the environment, society, and economic spheres. This section did not include learning goals related to either cognitive or affective outcomes related to sustainability.

Student Attitude Assessment

The research was reviewed by the University of Colorado Boulder Institutional Review Board (IRB) for human subjects research and deemed exempt category 2 due to minimal risk level (Protocol #21-0532).

The students from each of the 3 courses were invited to complete a short survey during class time near the end of the semester (December 2021). The research study was introduced using the IRB-approved script, making sure to emphasize that participation was fully voluntary and not linked to the course grades in any way. A hard copy of the consent form and survey was distributed, and students opting to participate completed the survey in about 5-10 minutes. In some cases, students indicated that they had already completed the survey in one of the other courses. In these cases, the students opted out and did not repeat the survey. In total, 212 students took the survey (representing a response rate of about 94% in Global Engineering, 56% in Introduction to Civil Engineering, and 36-85% in the First Year Engineering Projects courses); note that only students physically present during class on the date of the visit were given the option to participate. Student participation in each class was impacted by attendance on the specific day selected to give the survey.

The survey sought to understand student perception of the importance of sustainability in their profession and their confidence in tackling sustainability related issues. The survey was primarily multiple select with one open-ended question (see Appendix A). The survey used items from a previously published instrument that presented validation and reliability metrics [23] and has also been used in previous studies of sustainable engineering education [24]. Additional items were added by the authors that referred specifically to the course.

Survey Validation. The hand-written student survey responses were entered into a Google sheet. Negatively worded items then had the responses reversed. Next SPSS Statistical Software was used to conduct an exploratory factor analysis (EFA) and Cronbach's alpha. These tests were used to determine if items in the survey clustered together to measure particular constructs. The SPSS EFA using principal axis factoring and promax rotation with Kaiser normalization found that the 19 items loaded to 4 factors accounted for 47.798% of the variance; results are summarized in Table 4. The first 3 factors had reasonably strong reliability based on Cronbach's alpha. For Factors 1 and 3 there was not an improvement in alpha by deleting any of the 5 or 6 items that contributed to the factor, respectively. For Factor 2 a slight improvement in Cronbach's alpha to 0.784 was yielded by removing reverse scored item 6. Weaker loadings of reversed items have been noted in other studies (e.g., "negatively-worded items are indeed less reliable than positively worded items" [25] [26]). The fourth factor only had 2 items and a low alpha.

Table 4. Sustainability survey validity and reliability metrics

Factor	Represent	Survey Question Numbers	Percent of Variance	Loading	Cronbach's alpha
Factor 1 (Self-efficacy)	Student's self efficacy or confidence in their sustainability knowledge.	15-19	27%	0.774 - 0.846	0.906
Factor 2 (Intrinsic value)	Student's personal beliefs about the importance of sustainability, the reflective intrinsic value.	1, 13, 10 reversed, 5, 14, 6 reversed*	13%	0.855 - 0.283	0.757
Factor 3 (Extrinsic value)	Student's perceived extrinsic value of sustainability within engineering.	2, 8, 7, 9, 3, 4*	4.2%	0.724 - 0.342	0.725
Factor 4 (Course impact)	Impact of the course on the students.	12, 11*	3.6%	0.696 - 0.322	0.273

* in order of highest factor loading to lowest

Data Analysis. After the structure of the survey was evaluated, the average score for each of the 4 constructs was determined for each student. In addition, factors 1 to 3 were combined into a total ratio score (whereby each factor average was scaled to the maximum of 100, 7, and 7, respectively) and then added (for a maximum potential ratio score of 3).

To evaluate potential differences in student attitudes between courses, the non-parametric independent samples Kruskal-Wallis tests were conducted in SPSS (non-parametric does not require that the data are normally distributed). Given the low numbers of student responses (n) for some courses, the statistical threshold to infer a statistically significant difference was 0.10 (asymptotic sig.). This was followed by paired tests among the courses.

Note that some students skipped the demographic items. The items were located on the back of the page, so it is unclear if students consciously opted out or simply didn't notice those items when completing the survey.

Open-ended question. The single open-ended question on the survey was the first item. These responses were hand-typed into a spreadsheet. Many students skipped this question; there were 134 responses. Therefore, 63% of those who took the survey wrote-in a response. The question asked students: 'Describe how you view your future role in society as a practicing engineer.' The responses were examined for the following key words: sustainability or sustainable; the sustainability pillars of environment, economic, and society; renewable energy, climate change and EWB (Engineers without Borders). The responses containing these words were tallied. Additionally, common themes of responses were considered for each course.

Limitations. The students participating in the study would possess an array of different attitudes about sustainability before coming to college. The overall college experience and institutional culture may be impactful to their attitudes, in addition to students learning about sustainability in other courses (such as elective humanities and social science electives). Some students (13%) were enrolled in multiple courses (22 students in GlobalE were also in one of the FYEP sections, including 14 in one of the 3 sections in the current study; 6 IntroCivE students were also in a section of FYEP). If students were in multiple courses, their responses were averaged into both of the courses they took. Some students did not appear to be reading the items very carefully, as their responses to the negatively worded questions remained at the same Likert level as earlier responses. However, none of the respondents had an identical response across all of the 7-point Likert-type items. Acquiescence and social desirability response bias may cause the responses to not accurately reflect the true feelings of the students, despite attempting to limit these issues by including negatively worded items [26] [27] [28] [29]. It is also important to reiterate that given that in this SOTL study, the authors were also the course instructors. However, instructors traded classes when delivering the surveys. This kept instructors from giving the surveys to their own class(es).

Survey Results: Strongest Self-Rated Student Outcomes

Average student responses on the 7-point Likert-type items that were the strongest in each course are shown in Table 5 (italics indicate averages for the item that were not the highest) .

Table 5. Course strongest responses (bold)

Strongest survey item	GlobalE	Civil	FYEP -1	FYEP -2	FYEP -3
It is important for engineers to consider the broader potential impacts of technical solutions to problems.	**6.45**	*6.63*	*6.37*	**6.67**	**6.64**
Learning about sustainability concepts is a waste of time because I will never use that knowledge.	*6.26R*	**6.68R**	*6.24R*	*6.38R*	*6.36R*
I enjoy the creative aspects of developing solutions to meet present and future needs.	*6.10*	*6.26*	**6.39**	*6.21*	*6.36*

Three of the courses shared the same strongest survey item, acknowledging the importance that engineers consider the broader impacts of their engineering designs; students in the IntroCivE course had a similarly strong agreement with this item as students in two of the FYEP sections. In the FYEP-1 section students on average strongly agreed that they enjoyed creatively solving problems; the wording of ‘present and future needs’ alludes to sustainability. In the IntroCivE course the students most strongly disagreed that learning about sustainability was a waste of time; on average the IntroCivE students disagreed with this negatively worded item more than students in the other 4 courses. Thus, in all courses there were student attitudes that aligned with attitudes that one would expect to be supportive for engineers to embrace sustainable design.

Survey Results: Course Differences in Quantitative Items

Table 6 summarizes the average survey results from among students in each course. Course differences were statistically significant for course impact (sig. 0.083), self-efficacy (sig. 0.05), and overall (sig.0.049). The highest scores for course impact were found in the FYEP-2 course, perhaps indicating the value of project-based learning. The course impact responses were the lowest from students in the GlobalE course. This may be partially because the instructor indicated that he largely avoided using the term 'sustainability' in order to focus student attention on the immediate social needs of many humans struggling to survive today versus long-term environmental impacts. Looking at the two course items in more detail (Table 7), there was a statistically significant difference among the courses in the item "My confidence in solving sustainability related problems has increased because of this course." (KW sig. 0.005). Further, in four of the course settings the average "understanding of the importance of sustainability increased because of this course" ratings were higher than "My confidence in solving sustainability related problems has increased because of this course." The largest gaps were in the GlobalE course (difference 0.55) and IntroCivE course (difference 0.43). The one exception to this was the FYEP-1 course, where students were actively designing solutions to climate-related challenges which seemed to boost their confidence (6.00 vs. 4.88 for understanding importance).

Table 6. Average and standard deviation of construct values from each course

Course (n)	Course Impact	Self Efficacy	Intrinsic Value	Extrinsic Value	Total Ratio
GlobalE (117)	4.7±1.3	68±17	5.8± 0.9	6.1± 0.7	2.4± 0.3
CivilE (19)	5.1±1.2	78±13	6.2± 0.5	6.4± 0.4	2.6± 0.2
FYEP-1 (51)	5.0±1.4	74±15	5.8± 0.8	6.2± 0.6	2.5± 0.2
FYEP-2 (24)	5.5±0.7	70±11	5.7± 0.7	6.3± 0.3	2.4± 0.2
FYEP-3 (11)	5.0±0.6	72±7	5.9± 0.9	6.3± 0.4	2.5± 0.2

Table 7. Average ratings of course impact items among students in different courses

	Civil	Global	FYEP-1	FYEP-2	FYEP-3
My confidence in solving sustainability related problems has increased because of this course	4.89	4.46	5.03	5.42	4.89
My understanding of the importance of sustainability increased because of this course	5.32	5.01	4.88	5.50	5.00

For student self-efficacy or confidence, the highest values were among the students in the IntroCivE course. This may be due to the explicit learning objectives related to sustainability, which mapped to knowledge and skills and cognitive outcomes. Within construct differences, there are specific items that are interesting to note. For example, students in FYEP-3 rated their highest confidence in "Understand the interdependency among environmental, social, and economic aspects of engineering" whereas in all of the other courses the highest student confidence was in "Understand the meaning and application of sustainable engineering". In addition, among the five self-efficacy items students in the IntroCivE and FYEP-3 courses rated "Identify the social elements of an engineering project" the lowest (both courses taught by the second author), whereas the other courses were lowest in either "Identify economic elements of an engineering project" (GlobalE and FYEP-2) or "Understand environmental risks associated with engineering projects" (FYEP-1). Among all 5 courses, there was a statistically significant difference in "identify economic elements" (KW sig. 0.079). Given the random nature of students assigned to the FYEP sections, differences are more likely to be due to course content, whereas the particular focus of GlobalE and IntroCivE may have caused incoming differences in the students. A study with both a pre and post survey would be helpful to examine initial differences.

The lack of apparent differences among the intrinsic value and extrinsic value among students in the different courses indicates that this attitudinal interest and motivation aspects are perhaps more difficult to impact in courses. In addition, measuring these items with Likert-type survey items may be too inaccurate or subject to acquiescence / social desirability response bias.

Two additional individual items differed across the courses. Item 4 "Not all engineering problems have purely technical solutions" (KW sig. 0.100) was the highest in FYEP-2 (6.46), moderate in GlobalE (6.10), and the lowest in Civil (5.84). The other individual item where responses differed across courses was "My future career will likely involve solving local or global problems that may involve social, economic, and environmental issues" (KW sig. 0.083). Here, students in the Civil course agreed most strongly (avg. 6.21) and the GlobalE course was the lowest (avg. 5.17).

Survey Results: Open-Ended Question

At the start of the survey, students were presented with the request: "Describe how you view your future role in society as a practicing engineer."

Unique answers abounded across all courses. Some responses contained elements of sustainability while others did not. 37% of students opted not to answer and left this blank. Higher non-response to open-ended survey items is common, ranging from 15% to 75% in various studies [30] [31] [32]. The non-response to open-ended items is generally attributed to their higher cognitive demand than closed question types.

Table 8 includes the total number of students who included sustainability related wording. Note that some students are in more than one of these courses, and thus their responses were counted in each of the courses in which they were enrolled.

Table 8. Number of students with sustainability elements in the open-ended response

	GlobalE	FYEP	IntroCivE
Sustainability or Sustainable	9	7	1
Sustainability pillar wording: society, environment, economics	17	14	4
Climate Change	2	3	0
Renewable Energy	2	1	1
Engineers Without Borders	2	0	0
Total surveys	117	104	19
Total number of responses to this question	74	62	11
Total with any Sustainability related elements	25	25	6
Percent with Sustainability related elements	21%	24%	32%

Wording from the sustainability pillars, was the most common sustainability type wording that students included. IntroCivE had the highest percentage of students including sustainability in their vision of their future role as an engineer.

Some common themes presented themselves within specific courses, particularly in Introduction to Civil Engineering and Introduction to Global Engineering. The responses to First Year Engineering Projects were more varied and lacked unity, not surprising given the three different methods of sustainability integration.

Introduction to Civil Engineering

The students in the introduction to civil engineering course strongly related their future work as an engineer to sustainability or to human centered design. Only one of the 11 responses to the open-ended question, did not have one of these two elements. Here are a couple quotes from students in this course:

> "I want to take in the communities and build/design things that have the best social, economic and environmental impacts"
>
> "An aspiring engineer with an intent to innovate, create and build for the community."

Introduction to Global Engineering

Within the responses from the students in the Introduction to Global Engineering course to the open-ended question, there was an overall theme of holistic approaches to solving complex problems, demonstrating a strength in this course.

> "My role in society will be developing new technologies that benefit the human race by promoting sustainability, equality, liberty, and justice."
>
> "Not actively making the world worse - use engineering as a tool to address social and human rights issues."
>
> "This course has made me understand the importance of appropriate technology. I hope to use this to make the world more sustainable while also helping others in a way that makes sense."

FYEP

The responses in the First Year Engineering Projects course were more varied and less consistent. Here are a few of the responses:

> "I would like to use my engineering skills to help solve a major global issue like climate change, using renewable energies and green technologies."
>
> "Make technology for the betterment of society."
>
> "Important and meaningful"
>
> "Making sure all practices are taking the environment into consideration as much as possible."
>
> "Help improve quality of life"
>
> "Learning more about how we can maintain and grow sustainability in society."
>
> "I see myself informing future generations about how dangerous climate change can be and the positive impacts engineering can have on it."

Results by Major and Gender

A summary of the average survey results among students with different majors is provided in Table 9. Differences among the majors were statistically significant for intrinsic value (KW sig. <.001), extrinsic value (KW sig. 0.006), and overall (KW sig. 0.001).

Table 9. Average sustainability attitudes among students in different engineering majors

Major (n)	Course Impact	Self-Efficacy	Intrinsic Value	Extrinsic Value	Total Ratio
Aero (48)	5.0±1.0	73 ± 15	5.8 ± 0.8	6.2 ±0.6	2.4 ± 0.2
Mech (47)	5.4±1.4	73 ± 16	5.9 ±0.7	6.2 ± 0.5	2.5 ± 0.2
CompSci (17)	4.6±1.7	67 ± 23	5.7 ± 0.9	5.9 ± 1.4	2.3 ± 0.5
Civil (16)	5.2±1.4	79 ± 14	6.3 ± 0.5	6.4 ± 0.4	2.6 ± 0.2
Env (14)	5.2±0.8	76 ± 9	6.3 ± 0.7	6.2 ± 0.5	2.6 ± 0.2
Chem (8)	4.5±1.8	70 ± 9	5.4 ± 1.2	5.7 ± 0.9	2.3 ± 0.4

Differences by major in sustainability elements have been previously reported (REFS). Students who place intrinsic value on sustainability may be more likely to elect to major in environmental and/or civil engineering than other disciplines. In addition, these students may accurately perceive the strong (extrinsic) value of sustainability in these disciplines. Perhaps not surprisingly, the single survey item with the largest response difference among majors was "My future career will likely involve solving local or global problems that may involve social, economic, and environmental issues"; highest among civil and environmental engineering majors (avg 6.4), middling among aerospace and mechanical (avg. 5.4) and lowest among chemical engineers (avg. 4.5) and computer science (avg. 4.7).

In the case of the computer scientist, the wording of the questions including engineering could have yielded a negative response, because some computer scientists do not view themselves as engineers, while others do. For example, a quote from a student response to the survey is: "As a CS major, I struggle to imagine myself as a professional engineer."

Gender. When the survey results were explored between male and female students (Table 10), statistically significant differences were identified between male and female students for intrinsic value, extrinsic value, self-efficacy, and the impact of the courses (sign. 0.004, 0.079, 0.075, 0.055, respectively). Higher value of sustainability for women has been previously found. For example, a study with junior and senior students majoring in civil, environmental, and mechanical engineering found "significant differences in students' desire to address energy [27]. Higher self-efficacy (confidence) for male engineering students across an array of topics is common, but generally does not reflect actual higher ability [33].

Table 10. Average sustainability attitudes among male versus female students

Gender (n)	Course Impact	Self-Efficacy	Intrinsic Value	Extrinsic Value	Total Ratio
Male (125)	5.2 ± 2.6	73 ± 16	5.7 ± 0.8	6.1 ± 0.7	2.4 ± 0.3
Female (69)	4.7 ± 1.2	69 ± 17	6.0 ± 0.7	6.3 ± 0.5	2.5 ± 0.3

Intersections between course and individual student demographics are best explored in the GlobalE course, given its highest number of student responses (n=117). This is shown in Table 11. The same major and gender patterns seen in the data set overall were also found within the GlobalE course. Even within a single course the effects may be confounded; for example, 35% of the aerospace majors who responded to the survey were female compared to 70% of the environmental engineering majors.

Table 11. Results in GlobalE course only

Major or Gender (n)	Course Impact	Self-Efficacy	Intrinsic Value	Extrinsic Value	Total Ratio
Aerospace (30)	4.9 ± 1.0	71 ± 16	6.0 ± 0.8	6.2 ± 0.5	2.45 ± 0.24
CompSci (17)	4.8 ± 1.7	67 ± 23	5.4 ± 0.9	6.1 ± 1.4	2.32 ± 0.51
Mechanical (15)	5.0 ± 1.2	73 ± 21	5.9 ± 0.7	6.3 ± 0.6	2.48 ± 0.32
Environ (11)	4.4 ± 0.9	78 ± 10	6.2 ± 0.7	6.5 ± 0.6	2.59 ± 0.20
Male (60)	4.9 ± 1.4	69 ± 17	5.7 ± 0.9	6.0 ± 0.9	2.4 ± 0.3
Female (46)	4.6 ± 1.1	66 ± 18	6.0 ± 0.7	6.2 ± 0.6	2.4 ± 0.3

Given the ABET requirement for civil engineering programs to include sustainability, the end-of-semester student evaluations of teaching for civil engineering courses include ratings for "this course prepared me to consider the impact of engineering solutions in global, economic, environmental, and societal contexts" averaged 4.55 in IntroCivE compared to 4.44 in GlobalE and 4.15 averaged across all Civil Engineering courses.

Suggestions for Future Work

The researchers recommend that future studies administer the survey at both the beginning and end of the semester, to better understand incoming differences. In the future, the survey should also embed a 'check' item that asks students to input a specific response if they are reading the question within the Likert-style items; this would allow the removal of 'non-attentive' responses that could erroneously skew the data. Additional open-ended items on the end-of-semester survey might be insightful, such as asking the students to define sustainability or sustainable engineering and report any experiences during the semester which impacted their knowledge or attitudes about sustainability / sustainable engineering. A multiple linear regression model should be used to distinguish differences between students in different courses, majors, and gender, if a large enough data set is obtained.

In addition, it is believed that changes could be made to enhance student's awareness of the importance of sustainability within each course. In the FYEP course, small changes could be made in the syllabus to clearly identify the integration of sustainability. [See yellow-highlighted areas in the syllabus in Appendix B. For example, objective 4 could be modified to add the term "sustainability" to the range of considerations for design (alongside economic, environmental, and societal contexts). Sustainability could also be called out explicitly as part of learning objective 5 related to engineering ethics. In addition, sustainability might be added to two of the Engineering Habits of Mind: systems-thinking and considering ethics. While it is unclear that students are particularly attentive to the syllabus, addition to the syllabus should serve as a tangible reminder to faculty that sustainability is congruent and readily encompassed within the consensus-based learning goals for the FYEP course. The strongest way to improve student awareness and focus on sustainability is probably to add it explicitly to the rubrics used to grade student deliverables, including the team-based elements (e.g., critical design review) and individual assignments (e.g., written reflections). Examples of elements to include in such a rubric would be: ethics and environmental, social and economic factors.

Summary and Conclusions

Three unique first year engineering courses at the University of Colorado Boulder were evaluated for sustainability inclusion, particularly regarding the 17 UN sustainable development goals and Bloom's taxonomy. The sustainability inclusion for each course is described. Based on the discipline, student body, and course learning objectives, the sustainability inclusion content and methods were unique to each course.

The courses included in the study are Introduction to Civil Engineering, First Year Engineering Projects, and Introduction to Global Engineering. In seeking to understand student attitudes toward sustainability, students in each of these courses optionally participated in a survey. The survey included questions pertaining to self-efficacy, intrinsic and extrinsic values, and course impact associated with sustainability.

Survey responses yielded interesting findings including:

- Three of five sections (GlobalE and 2 sections of FYEP) had the strongest scores from students in the item 'It is important for engineers to consider the broader potential impacts of technical solutions to problems.'
- The results showed a lack of apparent differences among the intrinsic value and extrinsic value of sustainability among students in the different courses. It is thought that this may indicate that attitudinal interest and motivation aspects are perhaps more difficult to

impact in traditional engineering courses with sustainability inclusion vs. courses primarily focused on sustainability.
- The lead instructor in the GlobalE purposefully avoided using the word 'sustainability' in the course to maintain focus on the intra-generational aspects of sustainability. This may have led to a lower relation to the word.
- For student confidence/self-efficacy, the highest values were among the students in the IntroCivE course. This may be due to the explicit learning objectives related to sustainability in this course.
- When asked to "Describe how you view your future role in society as a practicing engineer":
    - Students in the GlobalE strongly related holistic solutions, appreciating the complex nature of the problems they will face.
    - Students in the IntroCivE course overwhelmingly included both sustainability and human centered design in their future engineering career.

Though none of the courses studied were solely dedicated to sustainability, each course had an impact on student perception of sustainability and on student intent to include sustainability in their engineering and life decisions. One student said: "I do not feel the obligation to devote my life to creating a sustainable world but what I do work on will be built with a sustainable mindset." We will continue to work to increase effectiveness of sustainability incorporation in order to increase student awareness and inclusion of sustainability in their engineering solutions.

Acknowledgements

The authors thank Dr. Evan Thomas and Dr. Katherine Ramos of the University of Colorado Boulder for participating in the research study.

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Appendix A. Survey

Complete the questions as honestly as you can, selecting the answer that best represents your beliefs.

Describe how you view your future role in society as a practicing engineer?

Please rate the level to which you agree/disagree with the following statements using the following scale:

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly agree	Agree	Strongly Agree

Prior to this course, the topic of sustainability was important to me.	1	2	3	4	5	6	7
It is important for engineers to consider the broader potential impacts of technical solutions to problems.	1	2	3	4	5	6	7
It is important to incorporate societal constraints into engineering decisions	1	2	3	4	5	6	7
Not all engineering problems have purely technical solutions.	1	2	3	4	5	6	7
It is important for me to learn how engineers can make the world more sustainable.	1	2	3	4	5	6	7
In engineering design, assessment of the potential impacts on economy, environment, and society is not important.	1	2	3	4	5	6	7
Engineers play an important role in improving overall quality of life.	1	2	3	4	5	6	7
I enjoy the creative aspects of developing solutions to meet present and future needs.	1	2	3	4	5	6	7
The ability to assess social, economic, and environmental implications of engineering designs is a useful skill that will help me be successful at my job.	1	2	3	4	5	6	7
Learning about sustainability concepts is a waste of time because I will never use that knowledge.	1	2	3	4	5	6	7
My confidence in solving sustainability related problems has increased because of this course.	1	2	3	4	5	6	7
My understanding of the importance of sustainability increased because of this course.	1	2	3	4	5	6	7
Practicing sustainability is a behavior that is a part of my everyday life.	1	2	3	4	5	6	7
My future career will likely involve solving local or global problems that may involve social, economic, and environmental issues.	1	2	3	4	5	6	7

Please rate your degree of confidence to perform the following tasks, on a scale of 0 to 100
(0 = no confidence; 50 = moderately confident; 100 = fully confident)

Understand environmental risks associated with engineering projects	0	10	20	30	40	50	60	70	80	90	100
Identify economic elements of an engineering project	0	10	20	30	40	50	60	70	80	90	100
Identify the social elements of an engineering project	0	10	20	30	40	50	60	70	80	90	100
Understand the interdependency among environmental, social, and economic aspects of engineering	0	10	20	30	40	50	60	70	80	90	100

Understand the meaning and application of sustainable engineering	0 10 20 30 40 50 60 70 80 90 100

Demographic Information

Please complete the following about yourself: (optional)

Year in school:_________________________________

Major:____

Gender:_______________________________________

Which of the following courses are you currently enrolled? (if applicable, select more than one)

☐ GEEN 1400 Engineering Projects: Instructor:_________________________

☐ CVEN1317 Introduction to Civil and Environmental Engineering

☐ CVEN2837/EVEN4830 Introduction to Global Engineering

Appendix B Syllabi Excerpts for Each Course

EVEN 2004 - Introduction to Global Engineering

Course Description

Goals of this course include:

1. Introduce students to the historical causes and present conditions of global inequality, and identify the opportunities and limitations of professional engineering engagement.
2. Empower students and working professionals to engage in a historically contextualized, anti-imperial contribution to global engineering.
3. Identify and promote the relevance and role of the engineering profession in supporting the reduction of poverty and increasing prosperity.

Learning Objectives

1. Students will identify the geopolitical and historical contexts of health and socioeconomic disparities within and between countries.
2. Students will describe global poverty reduction efforts, including historical and present-day programs, frameworks, funding agencies, and implementations.
3. Students will describe and critique technical interventions promoted to address water, sanitation, hygiene, energy, infrastructure, shelter, agricultural, and evaluation needs.
4. Students will design and assess programmatic Theory of Change and evaluation frameworks for global development interventions.
5. Students will criticize the role of professionals, including engineers, in poverty action, including identifying and reducing colonial, imperial and otherwise unjust practices in our professional fields.

Textbook and Materials

- Hickel, Jason, "The Divide" - Required
- Thomas, Evan "The Global Engineers" - Optional, PDF version provided through Canvas
- All other readings provided digitally in Canvas

Assignments

Attendance (Each class meeting is 1% of final grade, 30% total)

Attendance is required.

In-Class and Canvas-based Discussion (Graded as pass / fail / partial credit, 30% of total)

Weekly in-class and Canvas-based discussions will evaluate classroom and reading based learning, and facilitate classroom discussions.

Design Challenge Group Project (20% of total)

The Engineering for People Design Challenge will be conducted in groups. Students will work through the design cycle, development of functional requirements, product benchmarking, identification of design concepts and preliminary and critical design reviews.

Final Assignment (20% of total)

For your final assignment, you will develop a "Theory of Change" for a technology intervention of your choosing. To tackle this assignment:

1. Review the Demand Magazine archive, posted in Canvas. From these magazines, or from another(credible) source you identify, pick a case study where a technology was combined with an intervention targeting a poverty reduction or health improvement in a low/middle income setting.
2. Review the Theory of Change presentation from JPAL on Theories of Change.
3. Develop a Theory of Change for your chosen case study using the template provided in the modulefrom IFRC.

CVEN 1317: INTRODUCTION TO CIVIL & ENVIRONMENTAL ENGINEERING

The purpose of this course is to provide a foundation for your success as an engineering student and as a professional engineer. At the end of this course you should be able to:

1. describe what civil engineering is, what you may do as a civil engineer, the skills required to be a civil engineer, and similarities and differences compared to other engineering majors
2. describe the process to gain the skills required to be a civil engineer and successfully graduate with a degree in civil engineering from CU
3. explain the importance of professional licensure (PE) for civil engineers
4. describe the ethical behavior expected of civil engineers
5. define sustainability and describe its importance to civil engineering

You will probably find that your initial perceptions about civil engineering were too narrow. There is a vast diversity in the work done by civil engineers. This provides flexibility for you to find a subject which most interests you and to get a job to capitalize on your particular strengths....such as design, field work, technical innovations, writing, management, international travel, etc. A degree in civil engineering is also useful in a variety of other professions. This class will help you identify the skills that you will need to fulfill your goals.

Assignments

Your course grade will be determined primarily by homework assignments and 1 team project. Assignments are due before the beginning of class on the date shown.

Weekly Assignments [10 x 10 pts each] – based on a reading, video(s), or personal research
12 assignments but the lowest 2 scores will be dropped

Bridge Design Project [120 pts] – Individually design a bridge using Bridge Designer program and complete write-up. Compare bridges within a group. Turn in a group report describing how the best bridge was selected. Optimal bridges judged on stability under simulated truck load, minimum cost, environmental impact, societal impact, and creativity.

Final Term Paper [40 pts] Design your Process for Becoming a "World-Class" Engineering Student

Attendance and participation in class [20 pts]

Extra credit: you may raise your grade a maximum of 1 step (e.g. from B to B+) using extra credit points earned via optional surveys (in class and online) and other activities. Additional details in Canvas.

Week	Course Schedule: TOPICS	Assignment Due
1	Introduction to Civil Engineering kick-off	{1-IntroAFTERclass}
2	Overview of civil engineering: infrastructure & CE skills	2-Civil engineering overview
3	COVID discussion	3-COVID
4	Engineering design and Team bridge project introduction	4-Design
5	Mental health / wellness / resiliency	5-MHWR
6	Engineering Ethics	6-ETHICS
7	Diversity, equity, inclusion, racism	7-DEIR
8	Sustainable Engineering	8-SUSTAINABILITY
9	Creativity and innovation	9-Creativity
10	Team bridge project – work session	Individual bridge write-up
11	Team bridge presentations in class	Team bridges
12	Water resources / Environmental	Team Bridge Project Write-up
13	Structures / Geotechnical	10-Professional society
14	Construction Engrg & Management / Transportation	11-Internship
15	Overall wrap-up and final paper discussion	12-Research

GEEN 1400 First-Year Engineering Projects

Course Description:
The purpose of this course is to provide you an introduction to engineering through a series of projects done in interdisciplinary teams. You will learn in a hands-on way valuable engineering skills including communication skills, how to function in teams, and a variety of computer tools as appropriate to your projects, such as programming microcontrollers, dynamic modeling software, or computer-aided design (CAD). Specific learning objectives for the course include:

1. Open-ended Hands-on Design Experience: apply iterative design process to improve design; define functional requirements and specifications; generate alternative design concepts; work within constraints including safety; and appreciate and practice *engineering habits of mind* (see below).
2. Teamwork Skills: learn and practice effective teamwork skills; learn how to rely on other team members to give and receive help; demonstrate increased understanding of diversity, equity, and inclusion; and practice conflict resolution.
3. Communication Skills: develop a professional relationship with an engineering faculty member; develop technical writing and oral presentation skills; effectively communicate final designs to a range of audiences; and learn and practice active listening skills.
4. Engineering Methodology: build hands-on engineering skills for prototyping and manufacturing; practice the role of analysis in the design process; solve engineering problems with appropriate tools; and effectively apply technical skills to produce prototypes/design artifacts that consider a range of economic, environmental, and societal contexts.
5. Engineering Ethics: understand the importance of an ethical code for the practice of engineering; appreciate that difficult, 'gray' situations arise in engineering practice; and develop an ethical process that will yield appropriate decisions when needed.

Grading (weightings adjusted by each section instructor)

Group work: ~45%

Introductory project deliverables / report	15%
Team growth plan / reflections	5%
Final Design project deliverables / presentations	15%
Final Design expo / video pitch / report / website	10%

Individual accomplishments: ~55%

Spatial Visualization Mastery	5%
Safety, Saws and Drills Mastery	5%
Design website / journals	10%
Individual assignments / reflections	10%
Attendance and participation	10%
Skill development	5%
Peer evaluations	10%

The **textbook** for this course, *"Introductory Engineering Design: A Projects-Based Approach,"* is optional. It is available for free on-line as a PDF: https://www.colorado.edu/eplus/resources/introductory-engineering-design-textbook

Course Supplies and Project Budget:

An Electronics kit from Sparkfun is a required purchase for this course..

Additionally, the projects course requires students in teams to develop a multi-week design project that includes materials and fabrication of components specific to the project, as well as may require additional skills workshops after class hours. The budget for your main design project will be created with funds from you and your design team. *Each team member is expected to contribute up to* **$50** to fund any needed skills workshops and the main design project. Engineering design projects always consider economics, so if you are able to reuse materials from recycling or low cost sources, that is excellent [e.g. Ecocycle where folks drop off cardboard and other materials to be recycled].

ENGINEERING HABITS OF MIND	
Systems-thinking	Seeing whole systems and parts, and how they connect — recognizing interdependencies, and synthesizing. Equipping people to recognize essential interconnections in the technological world and to appreciate that systems may have unexpected effects that cannot be predicted from the behavior of individual subsystems.
Creativity and Creative Problem Solving	Inherent in the engineering design process; applying techniques from other traditions, generating ideas and solutions with others, providing generous but rigorous critiquing, and participating in engineering as a 'team sport'
Problem-finding, selecting & defining	Demonstrating a desire to solve real problems through clarifying needs, checking existing solutions, investigating contexts, and quantifying and verifying specifications
Visualizing	Moving from abstract to concrete, manipulating materials, practicing mental rehearsal of physical space and of practical design solutions
Improving	Relentlessly trying to make things better by brainstorming, experimenting, designing, sketching, guessing, conjecturing, thought-experimenting, and prototyping
Adapting	Testing, analyzing, reflecting, rethinking, changing (physically and mentally)
Considering Ethics	Drawing attention to the impacts of engineering on people and the environment. Ethical considerations include unintended consequences of a technology, the potential disproportionate advantages or disadvantages of a technology for certain groups or individuals, and other issues, including equity in access to engineered solutions
Demonstrating Optimism	Having a world view in which possibilities and opportunities can be found in every challenge and an understanding that every technology can be improved
Productively Respond to Failure	Living the adage that "experience is what you get when you don't get what you want," proactively learning and applying the knowledge and perspective gained from each design iteration to inform the next design.
Collaborating	Leveraging the perspectives, knowledge and capabilities of team member when addressing design challenges
Communicating	Essential to effective collaboration, to understanding the wants and needs of customers, and to explaining and justifying the final design solution within myriad constraints.

Adapted from: (1) National Research Council 2009. Engineering in K-12 Education: Understanding the Status and Improving the Prospects. Washington, DC: The National Academies Press. https://doi.org/10.17226/12635. (2) Lucas and Hanson, 2014, "Thinking like an engineer: using engineering habits of mind to redesign engineering education for global competitiveness," SEFI 42nd Annual Conference, Birmingham UK.