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# Range of Practices of Sustainability Incorporation into First-Year General Engineering Design Course


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# Range of Practices of Sustainability Incorporation into First-Year General Engineering Design Course


## Abstract

This work explored different methods of incorporating sustainability into a first-year engineering design (FYED) course. Each term at the University of Colorado there are 6-12 sections of FYED, each taught by different instructors from an array of departments. The general course learning objectives, calendar, and outline are provided for instructors but how they choose to implement these is uniquely their own. Even though sustainability is not explicitly included in the course requirements, several instructors choose to integrate sustainability topics into their sections of the FYED course. Each instructor does so utilizing unique methods. Faculty were interviewed about potential sustainability incorporation (or indicated a lack thereof via an email response). These descriptions of sustainability incorporation are compared with students' self-ratings of the extent to which the course impacted their preparedness in sustainable practices, and with self-perceptions of other course outcomes. The findings provide ideas for other instructors interested in incorporating sustainability into FYED courses.


## Introduction/Background

Sustainability is of growing importance in all aspects of life, and education is a key tool in increasing our sustainable practices [1]. The importance of sustainability in engineering is widely recognized, exemplified by its inclusion in the codes of ethics of a number of engineering professional societies and other guidelines [2] [3]. However, the interest and integration of sustainability into engineering varies across disciplines. For example, within the ABET Engineering Accreditation Commission (EAC) program criteria, sustainability is explicitly included within architectural, civil, environmental, and mining engineering [4]. Sustainability integration into courses in different disciplines varies [2] [5]. Therefore, integrating sustainability concepts into first year courses that are common to all engineering majors may help ensure that all engineering students are at least introduced to the concepts of sustainability.

There are many definitions of sustainability. Some definitions of sustainability include: capable of being sustained, of or relating to a method of harvesting such that the resources are not depleted, and development that meets the needs of the present without compromising the ability of future generations to meet their own needs [6]. Additionally in 2005, Amory Lovins, cofounder of the Rocky Mountain Institute, along with others, defined sustainability with the following characteristics [6]:

1. Dealing transparently and systematically with risk, uncertainty and irreversibility.
2. Ensuring appropriate valuation, appreciation and restoration of nature.
3. Integration of environmental, social, human and economic goals in policies and activities.
4. Equal opportunity and community participation/sustainable community.
5. Conservation of biodiversity and ecological integrity.
6. Ensuring inter-generational equity.
7. Recognizing the global integration of localities.
8. A commitment to best practices.
9. No net loss of human capital or natural capital.

10. The principle of continuous improvement.
11. The need for good governance.

Seay proposed a taxonomy of sustainable engineering and sustainable process design which included professional sustainability, environmental sustainability, social sustainability, economic sustainability, and sustainability methods and metrics [7]. The inclusion of these various constructs of sustainability in engineering courses can be evaluated, including FYED courses that are common in many programs [8].

Instructors are including sustainability in assorted ways in their courses, with different expectations for learning outcomes that range from cognitive to affective outcomes. The learning outcomes below specified in Minster et al [9], are applicable to this FYED course and the sustainability inclusion techniques.

- Defining, applying, analyzing and evaluating principles and tools of sustainable design.
- Defining, applying, analyzing and evaluating basic sustainability metrics.
- Learning how to apply concepts of sustainability to the campus and community by engaging in the challenges of sustainability solutions on the campus.
- Learning how to apply concepts of sustainability globally by engaging in the challenges and the solutions of sustainability in a world context.

The achievement of these sustainability-related learning objectives may be assessed in a variety of ways, including quizzes, pre and post surveys or exams, and through course assignments.

Discussing sustainability early in the curriculum and integrating it into several courses may help set an expectation among students that it is normal for engineers to consider sustainability in their work [9]. This idea of normalized sustainability was promoted at Purdue University, with a goal to integrate sustainability into courses across the engineering curriculum [10]. The work began with a faculty workshop in summer 2009 that had participation from 26 faculty across 10 different disciplines and with primary teaching responsibilities spanning first-year courses, engineering fundamentals, and senior / upper-level design courses. The 2010 paper lists 9 courses where sustainability modules were added as a result of the workshop, but longer-term impacts are unknown. As one example, Weber et al. [11] integrated environmental sustainability concepts and sustainable development ideas into 2 of 16 sections of a first-year design-focused course at Purdue University. The sustainability intervention was found to lead to gains in students' knowledge and confidence related to lifecycle assessment (LCA), but the study did not follow longer term impacts.

Within the context of design, different paradigms have been promoted in engineering. Sustainability for design is quite broad and complex and thus it has elements of human centered design (taking into account the human perspective in all steps of the design process), design for manufacturability (optimization of a product to create it easily and affordably) and multi-objective optimization (involves multiple criteria decision making and simultaneously optimizing more than one objective function). Additional information on this can be found in Morris et al. [12], Johnson and Gibson [13] and Ayer et al [14]. Morris et al contrasts typical pedagogy employed in engineering courses (theoretical, itemized, modular) versus design courses (integrative, holistic, problem-defining, human, applied) and indicates that the characteristics of design align well with sustainability [12]. Sustainability in engineering design is a focus of a 2014 book by Johnson and Gibson [13]. Ayer et al. explored the integration of open-ended sustainable design in a course with first-year architectural engineering students [14].

This paper presents additional models for integrating sustainability concepts into a first-year engineering design course.

## Methodology

This study explored the different ways that faculty integrated sustainability topics into a first-year engineering design (FYED) course, aligned with the Scholarship of Teaching and Learning. The FYED course at the University of Colorado has been studied for impacts on student retention for over a decade. The current study fits within the existing protocol to study the course which has been approved by the IRB at the University of Colorado (Protocol #11-0651). The institution itself is a large public R1 with ABET accredited degree programs in 7 departments. The institution generally has a strong reputation for sustainability efforts and has been highlighted in Best College Reviews for Top Green Colleges [15].

### Course Overview

The FYED course at the University of Colorado is required for the majority of the engineering majors at the institution. The course as a whole is coordinated by the Integrated Design Engineering Program, which supplies instructors for a number of the sections. In addition, majors that require the course for their students supply instructors for 1 to 5 sections of the course per year.  Within each section of the course the enrollment typically ranges from 20 to 30 students.

In the FYED course, engineering students solve real engineering design problems utilizing the engineering design process. The course is interdisciplinary and focuses on the iterative design process, team dynamics and teamwork, testing and analysis, presentation skills and technical writing. All sections complete one to two introductory projects at the beginning of the semester, and then one “main” project. The course culminates in a design expo where students demonstrate and present their main projects for the term.

There is a template syllabus provided to instructors, including learning objectives, recommended lectures, and recommended assignments. However, individual instructors have control over the specifics in their course, including selecting the type of preliminary projects and themes (or open topic) for the main project.

In the fall semester of 2021, a number of sections presented students with the project motivations from Jump Into STEM (which included equal access to healthy indoor air, resilience in the wake of disaster, and solving market adoption for emerging technologies). Other sections presented a local institutional ‘climate change’ challenge to students [16]. In comparison, in earlier semesters students were presented the Engineers Without Borders Design Challenge [17]. The topics for the main projects are dependent on the instructor’s interests and choice and are quite broad. Thus, students in the course may encounter a wide range of design experiences. This work seeks to identify and better understand those with sustainability inclusion.

Faculty Interviews

In fall 2021, 10 faculty were emailed by the first author and invited to participate in an interview to describe if and how they integrate sustainability issues into their section of the FYED course. Alternatively, faculty could choose to respond via email. A number of these instructors had taught the course in previous semesters.  Based on faculty participation in 2021, the number of instructors of the course represented by the study is six, four with sustainability (co-authors of this paper) and two without. In addition, information from one instructor who has frequently taught the course with sustainability is included. The co-authors explored how their courses included sustainability- related topics.

**Results**

Broad Framing

Sustainability inclusion is prevalent in three main areas: guest speakers, introductory project scope and final project focus. The sections had unique combinations of these, based on the instructor's and students' interests. Each could be implemented solo or together. Table 1 demonstrates the inclusion of each of these areas in several sections which included sustainability between Fall 2020 and Fall 2021.

Table 1. Sustainability Inclusion Overview

| Section (author) | Guest Speaker | General Sustainability Lecture | Introductory Project | Main Project |
|---|---|---|---|---|
| Section 1 (A3) | ✓ | | ✓ | ✓ |
| Section 2 (A4) | ✓ | | | ✓ |
| Section 3 (A1) | ✓ | ✓ | | (✓) |
| Section 4 (A1) | | ✓ | | (✓) |
| Section 5 (A1) | | ✓ | | ✓ |
| Section 6 (A2) | | | (✓) | (✓) |
| Section 7 (A2) | | | (✓) | (✓) |
| Section 8 (OI) | | ✓ | ✓ | (✓) |

Note: ✓ = included, (✓) = optionally included

Guest Speakers and Lectures

The FYED course general calendar provided for all instructors, included 3 set class periods dedicated to industry guest speakers.  Several instructors chose to bring in guest speakers who work in sustainability and could share their sustainability perspectives with students. The guest speaker selection process included seeking out individuals with knowledge and experience applicable to either the general topic of sustainability or to one of the design project themes. Due to current technological capabilities, guest speakers have been both local, presenting in-person and also afar, speaking via zoom. The guest speakers' areas of expertise varied greatly with the following examples: sustainable development in a global perspective, climate change, and sustainability and resilience in unique markets, such as prisons. The guest speakers provide insight into an area or field involved with sustainability.

Some instructors also chose to include one or more lectures specific to sustainability. Topics in these lectures have included: definitions of sustainability, a comparison of the inter and intra generational aspects of sustainability, sustainability pillars, the UN sustainable development goals and sustainability in engineering design. Popular active learning opportunities that have accompanied the lecture or guest speaker include learning about and performing Life Cycle Assessments (of a general item or of their design project) and personal carbon footprints.

Introductory Projects

At the beginning of the course, the students are welcomed with an introductory design project, spanning the first two weeks of the course. In select courses, sustainability options appeared in the introductory projects. One type of sustainability inclusion was to have the introductory project attend to a social issue. This was embedded in the project to create a light sculpture or billboard that addressed a social issue. Issues popular with students included recycling, for example. Other ideas were to have students design a solar cooking oven or a PVC water pump; these projects represent settings that often lack reliable access to grid power and avoid pollution associated with burning wood, coal, or other fossil fuels.

Main Projects

In the FYED course, students spend approximately ten to twelve weeks working on their main project. The main project includes working through the engineering design process. Students work to understand stakeholders and/or clients, define criteria, imagine solutions, and methodologically select a solution. They plan and then create prototypes. They evaluate and refine, all working toward their final solution and final product. The deliverables for their main project include a Preliminary Design Review, Prototype Demonstration, Critical Design Review, Functional Project, a Testing and Analysis Report, and a Final Report, Video, and/or Website.

Instructors of several sections of the course chose to include sustainability as an option or as an overall theme in the main project. This has presented itself in the unique ways described below.

Sustainability Inclusion 1

In the school year 2020-2021, three of the sections chose to include the Engineers Without Borders (EWB) Design Challenge as an option that students could select as the focus of their main design project [17]. This EWB Design Challenge is centered on the aspects of ‘meeting the needs of today’. The students were provided with a Design Brief with information about a community in Peru with specific challenges, including information about the built environment, water, sanitation, energy, waste, food, digital and transport. Students were also provided information on the area: history, climate, population, demographics, governance, maps and industries and employment. Students were tasked with utilizing the Design Brief to better understand the challenges in the selected area and to use human centered design to create a product that could improve quality of life in the selected area.

In the FYED course, student groups who selected the EWB Design Challenge as their focus, followed all of the same design steps and deliverables as the students with other design project foci. The student groups could then choose to submit their final report to the EWB Design Challenge competition. The competition proceeded to narrow and select top projects per university, subsequently top 8 in the nation, and lastly, award-worthy projects.

Examples of the projects conducted to student teams who elected to participate in the EWB Design Challenge included a community-scale composting toilet, a solar evaporative water desalination, water storage at height to use gravity driven micro-hydropower when the community experienced a power outage, an in-ground small refrigerator, design of a solar powered greenhouse, a water filtration system designed for usage in a river, and a landslide detection system.

Sustainability Inclusion 2
One section chose to include sustainability in the context of 'Sustainable Cities'. Students were shown the importance of design for the urban environment and were asked to think about urban needs. Climate change complications were also presented. The topic area was broad, and students were given a wide range within this context from which to select project topics. Potential topic areas briefly mentioned included water, sanitation, parks, recreation, and human well-being. Students were tasked with developing a new or improved product to assist human ability to thrive in an urban setting. Within the context of 'Sustainable Cities' students were asked to think about the following questions: What can you create that will impact the way people move about their day-to-day lives? What technologies can you develop to make an impact on people's habits and routines? What opportunities exist in this space for meaningful change?

Examples of student projects included a storm sewer power generation system, a bike lock-alarm solution, an automated plant watering and growing enclosure, a moisture sensing lawn sprinkler system, a rain catching water barrel system for apartment dwellers, and a white roof and contaminant filtering rain garden kit.

Sustainability Inclusion 3
In one section, the umbrella of 'Sustainable Futures' was given for selection of their Main Projects. Students were asked to envision a more sustainable future 30 years from now. Students were presented with the definition of sustainability of 'Meeting the needs of today without taking away future generations' ability to meet their needs.' They were also presented with the economic, environmental and social pillars of sustainability and the 17 UN Sustainable Development Goals. Students were asked to envision a world where more of the population had their needs met and in a way that could be sustained for future generations as

well.  Within this context students collected project ideas of products they would envision in the more sustainable future.

Examples of student projects included a solar powered lap desk, a phone charger powered by moving water, a sun-tracking solar cooker, a solar powered technology lock box and a water measuring and reporting device for the shower.

Sustainability Inclusion 4

Sustainability within climate change was the focus for one section. Students were asked to apply science, technology and engineering to solve carbon pollution problems and to communicate this in a way that can change people's behavior.  Students were given prompts from an organization that matches donors with student innovation in the area of climate change [16].  The prompts included topics such as accelerating the transition to electric vehicles, modernizing the electrical grid, bolstering campus sustainability, reducing residential carbon footprint, advancing regenerative agriculture, and addressing climate justice and community resilience.

Examples of student projects included a wind-powered turbine device used to charge a portable charging unit, a water-powered device used to measure and time water consumption in the shower, a rainwater harvesting garden bed used to reduce water waste, a gamified recycling unit which encourages recycling on campus, an "accountability clock" used to inform the public of climate change by including a countdown to irreversible climate change dates.

Outcomes Assessment: Student Survey

At the beginning and the end of each semester, the students enrolled in all sections of the FYED course were asked to complete an online survey; this survey was developed by the course coordinator (who was not teaching any sections of the course) and has evolved over the 20-year history of the course as part of assessment and evaluation [18]. The multi-person coordination team for the course routinely reviews the survey items for face validity, but have not conducted additional survey validation. At the start of the survey, students were provided the option to opt in to the research (if they are over 18 years of age) or take the survey for internal evaluation purposes only. The students typically login to the survey using their student ID, and then the institution links the demographic information for those students (e.g., their major, gender, etc.). In the pre survey, students were presented with 12 skill areas and asked to "rate how prepared you are to incorporate each of the following into your future endeavors", including sustainable practices. In the post survey students were presented with the same list of competencies but instead asked to "rate the extent that you improved your skills in each of these areas." Both questions used a 5-level response scale that ranged from not at all prepared (1), to very well prepared (5) on the pre survey and not at all improved (1), to extremely improved (5) on the post survey. The 12 skills listed are: public speaking / oral presentation, prototyping (laser cutter, 3D printing, sewing), engineering analysis and product testing, ethical reasoning, writing (technical reports), programming (Arduino, MATLAB, Python, etc.), sustainable practices, computer aided design  (CAD) and modeling, project management, electronics (circuit design, soldering), manufacturing (saws and drills, mills and lathes, CNC), and teamwork.

The student response data from Qualtrics were exported into Excel. Statistical analyses were conducted in SPSS and primarily included non-parametric tests appropriate for ordinal data. For example, Kruskal-Wallis tests were conducted to explore potential differences in student self-ratings among the multiple sections of the course. Due to the single survey item and small number of survey respondents, the usefulness of the quantitative data available is limited.

Respondents: On the fall 2021 pre-survey there were 282 individuals who completed the survey, consented to participate in the research, and completed the skills assessment questions. On the fall 2021 post survey there were 253 students who completed the survey, consented to participate in the research, and completed the skills rating questions. In total, 198 responses could be paired pre to post. The data from sections where the instructor participated in the study is summarized in Table 2 below. Note that this includes two "control" instructors who emailed that they did not include sustainability topics in their section. The same survey was also administered in fall 2020, and data from four of the same 2021 instructors is also included.

Table 2. Average sustainability ratings by students

| Instructor and term | Fall 2021 Post: 'extent **improved** skill in sustainable practices' (1 = not at all, 5 = extremely) | | | Fall 2021 Pre: '**prepared** to incorporate sustainable practices into future endeavors' (1 = not at all, 5 = very well) | | |
|---|---|---|---|---|---|---|
| | n | Avg $\pm$ stdev | Rank among 12 skills | n | Avg $\pm$ stdev | Rank among 12 skills |
| Section 1 (A3) | 41 | 3.1 $\pm$ 1.2 | 10 | 51 | 2.7 $\pm$ 1.1 | 8 |
| Section 2 (A4) | 11 | 3.5 $\pm$ 1.5 | 8 | 21 | 3.0 $\pm$ 1.2 | 6 |
| Section 3 (A1) | 13 | 3.3 $\pm$ 1.1 | 9 | 17 | 3.2 $\pm$ 1.0 | 5 |
| Section 4 (A1) | 24 | 3.0 | 11 | 24 | 2.8 $\pm$ 1.0 | 7 |
| Section 6 (A2) | 24 | 2.8 $\pm$ 1.1 | 11 | 30 | 2.7 $\pm$ 1.2 | 8 |
| Section 7 (A2) | 11 | 3.3 $\pm$ 1.0 | 10 | 23 | 2.7 $\pm$ 1.1 | 9 |
| Section 8 (OI) | 25 | 2.7 $\pm$ 1.0 | 8 | 23 | 3.1 $\pm$ 0.9 | 6 |
| Section 9 (OI) | 19 | 2.5 $\pm$ 0.9 | 11 | 19 | 2.5 $\pm$ 1.4 | 9 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Control1 F21 | 23 | 2.7 ± 1.2 | 11 | 16 | 2.9 ± 1.3 | 6 |
| Control1 F20 | 20 | 2.8 ± 1.2 | 11 | 14 | 3.3 ± 1.3 | 6 |
| Control2 F21 | 17 | 3.0 ± 1.1 | 8 | 22 | 2.5 ± 1.1 | 6 |
| FALL 2021 all | 253 | 2.9 ± 1.2 | 12 | 342 | 2.8 ± 1.1 | 7 |
| FALL 2020 all | 143 | 2.8 ± 1.2 | 12 | 216 | 2.8 ± 1.2 | 7 |

On the pre survey across all fall 2020 and fall 2021 sections, sustainability was rated at an average of 2.8, which was 7th highest among the 12 skills (ranging from high of 4.3 teamwork, well prepared, to 2.1 programming, slightly prepared). On the post survey in the level of skill improvement ratings at the end of the semester across all FYED sections, sustainability averaged 2.8 to 2.9 (~somewhat improved), which was the lowest of all of the 12 items; this compared to a high of 3.8 in project management. Among the sections included in this study, the highest average improvement scores in sustainability were in A4 section (Sustainability 2 inclusion of sustainable cities theme) and the fall 2020 sections of A1 and A2 that had some teams work on the EWB challenge. Interestingly, the range of improvement in the control sections (2.7 to 3.0) were not lower than the majority of the cases where sustainability was included. This shows the limitation of relying on a single item self-evaluated by students. Direct assessment of project deliverables would provide evidence (or not) of sustainability considerations in the projects, although not ‘improvement’ relative to baseline knowledge, skills, and/or attitudes among the students.

Further insights

PreSurvey. In the fall 2021 data, there were not statistically significant differences on the pre-survey in self-rated preparation for sustainability considerations among different sections of the course, which ranged from a high of 3.1±1.0 to 2.5 ± 1.0. Table 3 shows that this incoming confidence in preparation did vary among students in different majors.

Table 3. Pre-survey self-rated preparation for sustainability by major

| Major | Average ± Stdev | n |
|---|---|---|
| Environmental Engineering | 3.5 ± 1.0 | 10 |
| Mechanical Engineering | 2.8 ± 1.1 | 106 |
| Open Option Engineering | 2.6 ± 1.0 | 76 |

| | | |
|---|---|---|
| Aerospace Engineering | 2.6 ± 1.0 | 66 |
| Electrical Engineering | 2.5 ± 1.2 | 14 |

In the pre survey, there were statistically significant correlations among 10 of the other skills with sustainability (only public speaking was not significantly correlated), as shown in Table 4. These correlations on the pre-survey may simply reflect overall student “confidence” (uniformly high or low, more related to the Dunning Kruger effect than actual [19].)

Table 4: Statistically significant correlations among self-rated preparation for sustainability with other skills (2-tailed significance <0.001)

| Skill | Spearman rho Correlations |
|---|---|
| Engineering analysis and product testing | 0.478 |
| Project Management | 0.452 |
| Prototyping (laser cutter, 3D printing, sewing) | 0.389 |
| Ethical reasoning | 0.385 |
| Programming (Ardunio, MATLAB, Python, etc.) | 0.377 |
| Computer Aided Drafting (CAD) and modeling | 0.371 |
| Electronics (circuit design, soldering) | 0.364 |
| Writing (technical reports) | 0.362 |
| Manufacturing (saws and drills, mills and lathes, CNC) | 0.341 |
| Teamwork | 0.246 |

Post Survey

In the post survey, the increase in sustainability skills reported among students majoring in environmental engineering was the lowest among the majors (average 2.58). This is to be expected since these students reported the strongest incoming confidence on sustainable practices. On the post survey, there were not statistically significant differences in self-reported increases in sustainability skills across all 12 of the sections (Kruskal Wallis), but this test was limited by the low n in some sections. A pairwise comparison of the highest section (20, avg. 3.55 + 1.51) to the weakest section (40, avg. 2.18 + 1.14) found a statistically significant difference in a Mann Whitney U test (asymptotic sig. 0.017). In the post survey it was also observed that all 11 of the other skill gains were positively correlated with sustainability skill gains. The strongest correlations were with ethics (rho 0.571**) and writing (rho 0.457*). Due to the understanding of macro ethical issues, a correlation between sustainability and ethics is expected. However, correlations with the other elements appear to indicate global “learning” or positive attitude toward the course as a whole.

## Comparison of Pre and Post

One might expect that students who self-rated their preparation low on the pre survey would experience greater gains in their skills, thus an inverse correlation between pre and post ratings. However, across the 198 paired responses among the fall 2021 students, only prototyping and CAD showed weak negative correlations (but not statistically significant). In 10 of the 12 skill areas the pre to post correlations were weakly positive (although only statistically significant for electronics with a Spearman rho of 0.156, sig. 0.028; for sustainability rho 0.100 with sig. 0.164). However, this analysis lumping all the sections of the course together is confounded by different emphasis on the various skills across the sections. Within section 10 for example, only ethics had a weakly negative correlation (rho -0.348, sig. .104) and 11 of the 12 skills had weakly positive correlations (only significant for engineering skills). The positive correlations between initial skills assessment and self-reported gains may be due to students tending to work within their areas of comfort. For example, a question on the post survey asked “how often did you take on tasks that were completely new to you, out of your comfort zone, during your projects course this semester?” The responses were: 14% always, 56% often, 27% sometimes, 3% rarely, and 1% never. Thus, students with some degree of skill or confidence would focus in particular areas. However, sustainability is a cross cutting theme that it is hoped all students could engage with, in contrast to more focused areas of expertise such as programming and CAD.

Within particular sections there were some interesting correlations found. For example, Section 1 with A3, (n=16) the correlation was -0.495. This indicates that students with stronger initial feelings of preparedness regarding sustainability reported smaller improvements; this is logical. The correlation for sustainability was the strongest among the 12 skills rated by the students. However, in the other section taught by the same instructor there was not a significant correlation, but this may be due to the low number of students who completed both surveys and consented to participate in the research (-0.05, n=7).

## Limitations

The key limitation is that a single item on a survey to evaluate students’ self-perceptions is inadequate. In addition, a question about the extent that a student improved their skills can be related to multiple factors. First-year students in the FYED course were potentially enrolled in other courses that could have shifted their improved skills. Further, both students and faculty likely define ‘sustainable practices’ in the context of engineering design differently. The results should not be considered transferable or generalizable. The goal of the paper was to present ideas for others with an interest in incorporating sustainability into first-year design courses, not to conduct rigorous engineering education research.

**Discussion**

This work investigated and documented various sustainability inclusion practices in several sections for a first-year engineering design course at the University of Colorado. The sustainability inclusion practices are briefly described in this paper to offer ideas and insight to those wishing to include sustainability in their first-year engineering design course. Inclusion efforts included the broad areas of lectures, guest speakers, introductory projects and main design projects. Data on student perceptions of their improved skills (post-course) and their preparedness to incorporate sustainable practices (pre-course) from the normal course survey provide some insight into the effectiveness of the sustainability inclusion measures. More robust assessment methods could include direct evidence in student reports and presentations. Anecdotally, other course instructors verbally indicated an interest in sustainability but felt unprepared to integrate this into their own section.

Key takeaways

- There's not one right way to include sustainability into a design course. There are a variety of effective methods of including sustainability in an engineering design course.
- Instructors do not have to be experts in sustainability to include it in their design course. There are external options, such as guest speakers, who can provide sustainability expertise.
- By planting the seed of sustainability and the need to consider sustainable engineering practices, students demonstrated a stronger sense of commitment and accountability to their projects and project goals.
- This generation of engineering students are well informed about the need to consider sustainability and are therefore more receptive to having sustainability included in their design courses.

Lessons learned

After various sustainability inclusion efforts, the following lessons have been learned.

- It is helpful to leave the project scope fairly open to allow student choices to find an area of their interest.
- Calculating a life cycle assessment on the student's project can assist students in grasping sustainable design.
- Looking at the contributing factors in calculating personal carbon footprints can help students to relate sustainability concepts to their own life practices.
- While student projects may initially focus attention on broader sustainability concerns in the early scoping phases, students often become technically focused on their "builds" later in the semester; requiring students to refocus their attention on sustainability issues in a final report or presentation may help solidify sustainability concepts.
- If instructors are truly committed to communicating the importance of sustainability in engineering, grading rubrics should include sustainability.
- Sustainability projects can be daunting/intimidating for first-year engineering students to take on; however these same students demonstrate a growth mindset and comfort when presented with tools and resources to solve these challenges.

This work seeks to increase resources available for instructors wishing to incorporate sustainability into their first-year engineering projects courses. This early exposure of engineering students to sustainability concepts in the context of engineering may help the next generation of engineers to embrace this commitment.

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