# Integration of ethics in sustainability in a first-year design course

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## Abstract

This *Complete Paper - Evidence based practice* details the integration of engineering ethics in a first-year, first-semester engineering course at Bucknell University with the theme of sustainability. The cornerstone course teaches engineering design in a hands-on fashion with student groups tackling design projects that aim to address sustainability issues on campus. Previously, engineering ethics was introduced separately during a stand-alone and disconnected "ethics week". This paper will provide details regarding the current implementation of ethics content, which is delivered in parallel with project progress and more closely relates to the design projects. Specific approaches include in-class team activities, case study review, individual scenario assignments, a team-based ethics simulation (previously developed and presented at ASEE), design project reflections, discussions of ethics through the lens of the three pillars of sustainability, and an individual final paper related to an on campus sustainability ethics scenario. In addition to providing an overview of ethics activities and assignments, this paper will compare course-level student learning outcomes between the current and prior years and how content in the course affected students' perception of engineering ethics. We expect that by more closely integrating ethics content with the student projects, students will engage more deeply with ethics and appreciate how engineering ethics affects everyday engineering practice, thus improving the self-reported learning outcomes of the course.


## Introduction

Many universities require a first-year cornerstone course for incoming engineering students, and Bucknell University is no exception. One version of the college-wide introductory course, adopted in the 2002-2003 academic year [1], involved seminar-based instruction related to the disciplines of engineering as well as a separate week introducing engineering ethics. The course format was recently revised to a project-based course in the 2021-2022 academic year [2] but the pilot year maintained a separate week of standalone instruction for engineering ethics. The purpose of this paper is to document the ongoing adjustments made during the second iteration of the project-based course (2022-2023 academic year) to more intentionally incorporate engineering ethics into the project-based portion of the course. Research indicates project-based courses and embedment of transferable or professional skills within technical context are advantageous [3, 4, 5]. It was expected that this change would improve student learning and affinity for engineering ethics, which is not often a highlight in students' minds.

The specific approaches are described and a comparison of the self-reported achievement of course-level student outcomes related to engineering ethics is provided to demonstrate that more closely coupling ethics content with the project component of the course yielded an improved level of engagement and appreciation for engineering ethics from first-year students.

## Background

Bucknell University is a predominantly undergraduate institution with a College of Engineering situated within the liberal arts context. The College of Engineering enrolls approximately 200 students each year, currently divided among eight degree programs (Biomedical, Chemical, Civil, Computer, Computer Science, Electrical, Environmental, and Mechanical Engineering). ENGR 100 is the introductory course required for all incoming first-year engineering students

and open to students in the other two colleges - Arts and Sciences and Management. This course is one of four courses in the common, first semester curriculum for all engineering students.

The college-wide ENGR 100 course was recently revised by an interdisciplinary team of coordinators beginning in 2021 as project-based and is described in more detail elsewhere [2]. The pilot year of the revision focused on developing the central project-based learning component of the course, thus maintaining a separate standalone week of instruction on engineering ethics until the 2022-23 academic year when it would be more intentionally incorporated. The course was re-envisioned with a course-wide, unifying theme for all projects: sustainability on campus. During the pilot year (2021-22 academic year), the semester was organized such that after a week introducing the engineering design process, each student team of 4-5 students would tackle their first project for the first six weeks of the semester. After a culminating expo, the student teams and associated instructors would be shuffled and each new student team would tackle their second project with a new instructor for another six weeks of the semester. After a culminating expo, the final week of the semester focused on engineering ethics. "Ethics week" involved traditional exposure to the NSPE Code of Ethics, case studies, an online ethics simulation [6], and a final paper involving the analysis of an engineering ethics case study.

While the format of "Ethics Week" elevated engineering ethics to the sole focus of the course, it also seemed to come as an afterthought or separate from the engineering design of the two six-week design sessions, particularly from the student perspective. The course redevelopment team also recognized other shortcomings of the current approach. The case studies used often depicted high stakes situations implying that ethical situations rarely occur. The chosen case studies also made the "right thing to do" fairly apparent such that students did not engage deeply with the case study or struggle to decide what to recommend --- they simply responded as expected by their target audience, their instructor. The case studies also rarely included relevant design decisions, but rather highlighted how managerial or logistical decisions impacted the outcome such that students were not considering the ethical nature of their design decisions throughout the engineering design process.

Several degree programs within Bucknell's College of Engineering utilize this introduction to engineering ethics in ENGR 100 as the foundation of their engineering ethics education to fulfill ABET's associated student outcome 4 (old outcome f). The coordination team established a course-level goal (1 of 4 for ENGR 100) to "Employ the NSPE code of ethics to examine ethical case studies and extrapolate principles for other situations".

**First-Year Engineering Ethics Overview**

The challenges with teaching engineering ethics in a first-year course are not unique to Bucknell. Literature shows that many improvements have been made in the development of learning outcomes, content, and pedagogy for engineering ethics [7] but it is not yet apparent which interventions are the most effective. The most popular pedagogical strategies include:

- Introduction to codes or rules
- Case Study Exposure
- Discussion or debate
- Individual written assignments
- Ethical tools, processes, or heuristics

- Philosophical ethics
- Team project/position paper

Despite the improvements in content and pedagogical strategies, educators are often still stymied by the structural barriers that exist within their course, program, or institution [8]. The most noted barrier noted that engineering ethics is typically relegated to the overcrowded first-year and capstone courses. This is often attributed to the belief that ethics is an "add-on" rather than a core competency of engineering. There is also a dearth of faculty eager to teach or develop new ethics-related content. In addition, first-year courses are often provided across multiple sections where instruction consistency is challenging to ensure.

While these challenges do exist at Bucknell University, the coordination team felt that we also had an opportunity within the larger course redesign to improve the engineering ethics component of the course and reduce the issues previously identified. The use of sustainability as a context for engineering ethics is also common and includes a wide array of case studies and examples [12]. It was hypothesized that by integrating engineering ethics into the design project, it would be more valued by the students and not perceived as an "add-on" to the core of the course. It was also anticipated that including case studies that represented a range of consequences (real life/death situation to daily ethical reasoning in design), possibly through the lens of the course-wide theme of sustainability, would reduce the perception that ethical decision making is a rare occurrence.

**Methodology**

*Framework and Introduction*

The ethics framework utilized in this course is based on the text and analysis process developed by P. Aarne Vesilind. His text, The Right Thing to Do [11], establishes ten moral values, as defined by philosopher Bernard Gert, as the fundamental dilemma components of any ethical situation:

1. Not killing others
2. Not causing pain
3. Not disabling
4. Not depriving freedom
5. Not depriving pleasure
6. Being truthful
7. Keeping promises
8. Being honest
9. Obeying the law
10 Doing your duty

Vesilind's approach to making an ethical decision is described as a logical mapping process, which we call the Vesilind Process, where one critically responds to the following eight questions surrounding a given situation:

1. What are the relevant facts?

2. What are the moral issues and conflicts?
3. Who is affected by the decision you have to make?
4. What are your options?
5. What are the expected outcomes of each possible action?
6. What are the personal costs associated with each possible action?
7. Where can you get some help in thinking through the problem?
8. What is the right thing to do?

Note that NSPE Code of Ethics is an integral part of the Vesilind Process, as it is specifically referred to as one of the resources to be utilized in the answering of Question 7. The goal of the Vesilind process is to separate "gut feelings" and ethics by employing a more fact-based, guided decision making process that can be used by most engineers. For each ethics scenario presented in the course, a tabular worksheet with the above eight questions was used by the individual student or team. Questions 4-7 were to be answered for each of non-specified number of possible actions so that students can synthesize a full picture of the scenario at hand.

The Vesilind process was first introduced to the students in the context of individual, realistic, personal ethical scenarios surrounding academic integrity. Students were challenged to engage in a topic close to home, as Bucknell University's Honor Code was reviewed and discussed, before engaging with more complex and engineering-specific ethical scenarios. The instructor transitioned to one of the common case studies of engineering professional ethics:well-known historic engineering disasters resulting in life/death situations. An interactive ethics case simulation [6] was employed for students to experience a situation that involves a string of seemingly regular and less critical decisions (rather than a single life/death decision) that contribute to the determination of the final (possibly catastrophic) result.

*Environment and Sustainability*

In previous renditions, the course utilized several additional case studies of engineering disasters representing various disciplines within engineering. With the recent redesign of the course [2] toward project-based learning with a central theme of sustainability, the lens through which the students learn engineering ethics was intentionally selected to reflect the course theme. The presentation of historical ethics case studies was kept to a minimum. Instead, engineering ethics was framed within the context of sustainability while the students were simultaneously working on projects related to sustainability on campus, and relevant discussions were thus dispersed throughout the semester.

Following the theme of the course, ethical discussions focused on the tensions between the three pillars of environmental, economic, and social sustainability. As a result, discussions and student responses represented multiple facets of the dilemma, as the "right" answer was not as obvious. Aside from the prominent cases of environmental disasters impacting the health and wellness of

lives and communities like the Flint Water crisis, the environmental sustainability discussions lead to much more nuanced ethical evaluations of protecting non-human lives (animals, insects, plants). Economic and social sustainability dimensions lead to ethical discussions of not necessarily life-or-death dilemmas, but rather prioritizations and cost-benefit analyses of engineering designs, decisions, and actions. It is believed that these sustainability-related ethical considerations are not only important but also more tangible and engaging to first-year students than the far-removed topics of historic disasters that they did not live through themselves.

*Assignments and Direct Assessment*

While the design projects and project-specific assignments vary across eight different instructors in the course, we have common assignments and rubrics, as well as common timing of activities, for the ethics related content of the course. This is partially because engineering ethics is an ABET student outcome directly assessed in the course and utilized by some programs within the College of Engineering. These assignments follow a typical format of presenting a case and prompting students to analyze the scenario utilizing the Vesilind Process to determine a final decision, but the cases given are hypothetical and/or fictitious, intentionally set in the present or future.

The first assignment is based on Business Ethics Case Studies: The Polluter's Dilemma [13], and frames a scenario in which one is a working environmental engineer in a fictitious plastics manufacturing plant. The engineer is asked to make a decision to install an emission mitigation system for cleaner wastewater, at the expense of going over the plant budget. Unlike typical case studies, the ethical dilemma is not immediate or about life-or-death of human beings. This intentional focus on aquatic and non-aquatic life, as well as the uncertainty of time for the emission to impact the society lead to a realization that arriving at an ethical decision is more nuanced and complex even if one follows the Vesilind Process and/or the NSPE Code of Ethics. This assignment is not directly assessed for ABET and can be found in the Supplementary Materials.

The second common assignment was directly assessed for ABET Student Outcome 4, “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.” We framed hypothetical scenarios where our University considers the construction of a wind turbine for sustainable energy generation on campus. With limited details and first-order assumptions, we identified three different realistic, possible sites to build a wind turbine, as seen in Figure 1. The scenarios given to the students were realistic and complex, but not leading to catastrophic tragedies. By guiding the students to follow the Vesilind Process in the context of three pillars of sustainability, we expected the students to think critically and holistically in arriving at an ethical decision.

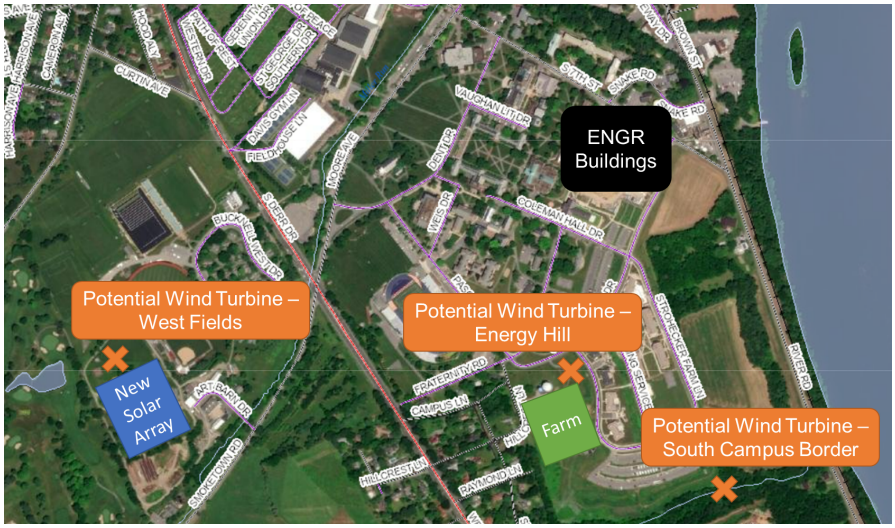


Figure 1. The three different sites for a new wind turbine

Each possible site was provided with clear advantages and disadvantages in terms of impact to sustainability on campus. The first location is superior for economic sustainability, the second location is superior for social sustainability, and the third location is superior for environmental sustainability. We were interested in a focused, compartmentalized ethics analysis by our first-year engineering students, and thus we only assigned each student to consider one of the three sites. The scenarios given to the students were realistic and complex, but not leading to catastrophic tragedies. By guiding the students to follow the Vesilind Process in the context of three pillars of sustainability, we expected the students to think critically and holistically in arriving at an ethical decision. The full assignment from Fall 2022 can be found in the Supplementary Materials.

The culminating final assignment, in the form of a take-home final paper, was an extension of the previous wind turbine construction assignment. Instead of being constrained to one particular site, the students were given all three possible sites to consider, which broadens the student's view on the types of ethical considerations to be made. The students were forced to make "the right decision" when there is no clear cut correct decision. The final assignment, which can be found in the Supplementary Materials, focused both on the synthesis of the ethical decision and developmental reflection on the assignment. This assignment was used as a direct assessment for ABET Student Outcome 4, with one of the questions specifically prompting students to recognize components of their design projects that may have ethical considerations.

**Results and Analysis**

Results from student surveys and course assessment tools include self-reported progress on the ethics related, course-level learning outcome, perceived impact of specific ethics course components on shifting ethics perspectives, and student comments from end of semester evaluations. All student survey and course evaluation data are from Bucknell University

Institutional Review Board approved study number 2223-001. Generalized faculty perspectives are also provided.

*Student Survey Numerical Results*

For self-reported learning outcome progress, comparisons were made between the Fall 2021 course offering and Fall 2022 course offering. The course-level learning outcome remained identical between academic years, as follows - "*employ the NSPE code of ethics to examine ethical case studies and extrapolate principles for other situations*". Students were asked to self-report how they progressed on this outcome with the following options - extremely well (EW), very well (VW), moderately well (MW), somewhat well (SW), and not well at all (NWA). Between the fall of 2021 (184 students who completed the survey) and and fall of 2022 (188 students who completed the survey), there were no statistically significant differences ($p = 0.34$, Wilcoxon rank sum test) in the self-reported learning outcome progress (Figure 2).

These results suggest that alterations made to the course between years did not negatively impact learning related to employing the NSPE code of ethics in specific case studies covered in the course and applying the code of ethics to other scenarios that may be outside of course content, as reported by students. While an increase in self-reported learning outcome progress between fall 2021 and fall 2022 would have been beneficial, the primary purpose of redesigning ethics content was to increase the perceived value of ethics and increase a sense among students that ethical decision making is not uncommon in engineering practice, which may not be captured by this survey mechanism. Nonetheless, consistency between years and the median reported outcome of students progressing "very well" (Figure 2) suggests course materials effectively introduce the NSPE code of ethics as a resource for students.

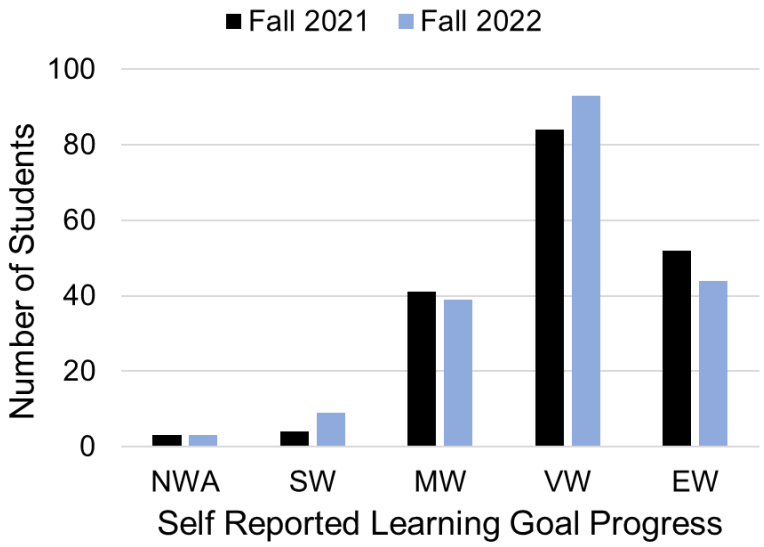

Figure 2. Student evaluation results of self-reported progress on the following learning goal – *employ the NSPE code of ethics to examine ethical case studies and extrapolate principles for other situations*. Bin labeling is NWA: not well at all, SW: somewhat well, MW: moderately well, VW: very well, and EW: extremely well. Differences in the two distributions are not statistically significant ($p = 0.34$), as evaluated by a Wilcoxon rank sum test.

In a separate survey, students were asked to rank how different ethics-related components of the course impacted their perspective on engineering ethics (Figure 3). Course ethics content included the Vesilind textbook, a Google Sheets worksheet template for students to complete the Vesilind Process, two individual assignments (as detailed above), a group live-action simulation [3], in-class discussions that ranged from an introduction to the NSPE code of ethics to ethical dilemmas facing different sustainability topics, and the final paper assignment (also detailed above). The live action simulation, in-class discussions, and Vesilind Process worksheet were perceived as most impactful, while the final paper and Vesilind text were perceived as least impactful. These results suggest that ethics activities completed in collaboration with peers or in groups have a greater impact on students' perspective of engineering ethics in comparison to individual activities. Prior research that has shown group work and class discussions for ethics content was preferred by students in comparison to reading or passive lecturing supports our findings [9]. Future work to further probe differences in ethics-related learning between individual and team activities would be a benefit to first-year engineering pedagogy.

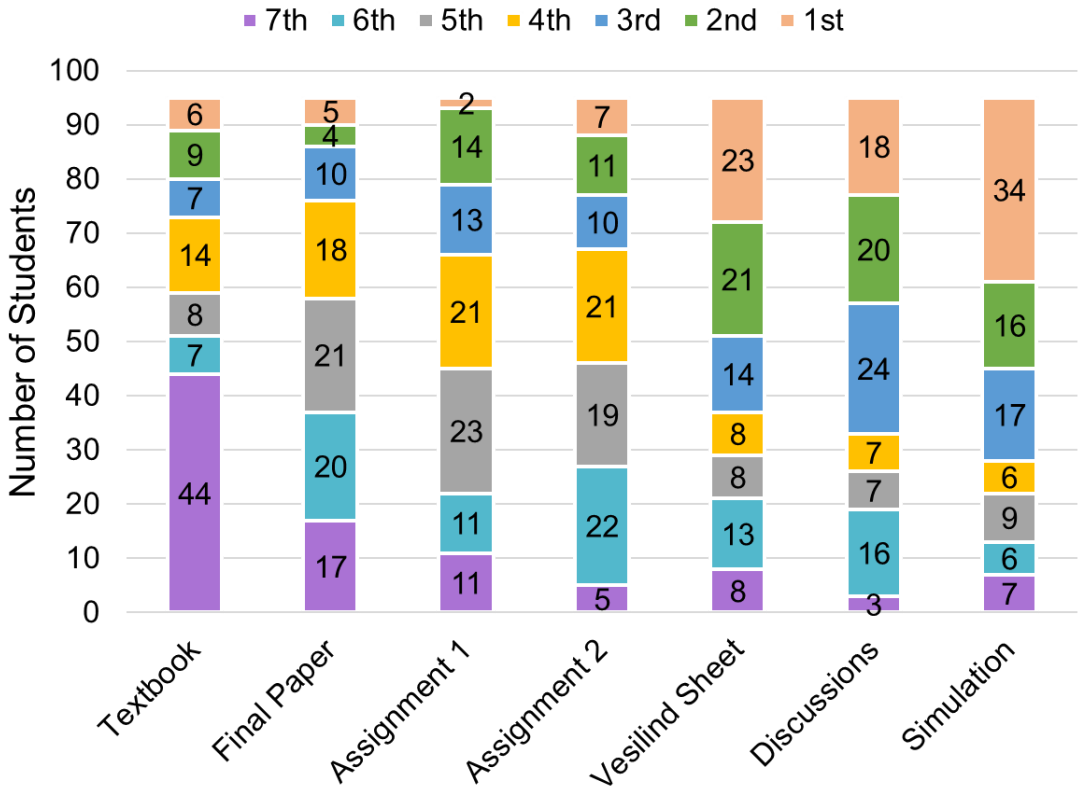

Figure 3. Student survey results of perceived impact of ethics components. Students (n=95) responded to the following prompt - *thinking about the ethics segment of the course, please rank the class component according to their impact on your perspective, from greatest to least*.

*Student Assessment Results*

For all 206 students, the average score (out of 100) on the initial wind turbine assignment was an 82.2 (median of 85), while the average score (out of 100) on the final ethics paper was an 84.2 (median of 86.7). The highest numerical scores were observed in the first prompt (Figure 4), which asked students to reflect on the initial wind turbine assignment. Conversely, the lowest scores were observed in the final prompt (Figure 4), which asked students to extrapolate their knowledge of engineering ethics by identifying one or more conflicts between moral values that are relevant to their design project. While repetition is a common approach for skill development, extrapolation of course content is valuable for complex problem solving, a major need in engineering education [10]. Thus, balancing repetition and extrapolation in engineering ethics case studies and activities should be carefully considered by educators.

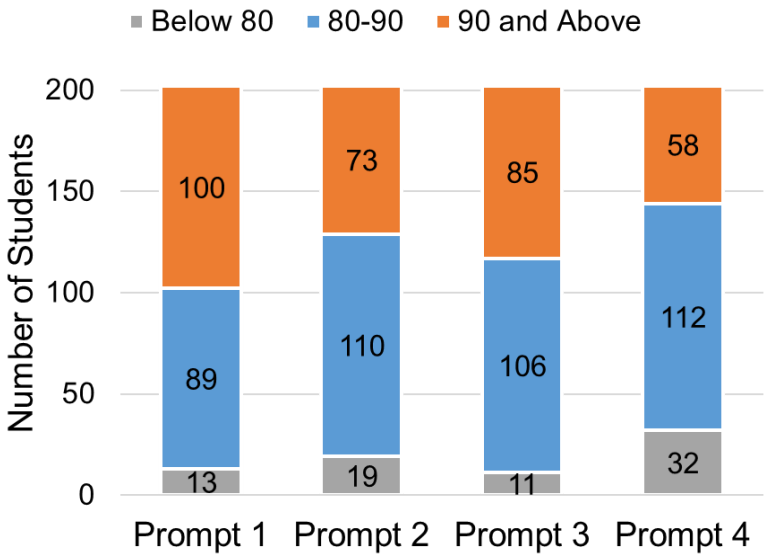


Figure 4. Final wind turbine paper assessment results for each of the four prompts. Prompt 1 - *Reflect on your [second common] assignment.* Prompt 2 - *do you recommend constructing the wind turbine (or not) and why? If so, which location would you recommend and why?* Prompt 3 - *How does your recommendation impact the* [three pillars of sustainability]*?* Prompt 4 - *Identify a facet of your DS2 design project which involves an ethical dilemma and discuss briefly*.

*Student and Faculty Perspectives*

Students were also provided opportunities to comment in open form within the above surveys. Comments from the Fall 2021 offering of the course highlight the lack of ethics integration into the design aspects of the course:

> *"The Ethics Week at the end felt a bit out of the ordinary coming after two design sessions back to back."*

For the Fall 2022 offering of the course, students noted the planned integration of ethics into Design Session 2:

> *"Additionally, the ethics were integrated into the DS2 seamlessly allowing the whole process to be more realistic and give me a solid understanding of engineering ethics"*

> *"…the aspect of ethics in this course was a benefit as well. [It] was the first time I have been introduced to [ethics] and I think that learning about ethics and how to apply it to situations helped me and my team in making decisions on our project…"*

> *"It made the engineering ethics much more **real** to me, and I didn't really think about it that much in this type of context"*

> *"I think the ethics content really helped me understand why engineers do the things they do."*

However, this observation of integrated ethics and design was not perceived as being valuable to all students, with a small number preferring a separation of design and ethics. Furthermore, this separation is contrary to the role of engineering ethics in professional practice:

> *"[ethics] disrupted the flow of the engineering project…maybe allow more time in the course to focus specifically on [ethics]"*

Overall, the above commentaries support our hypothesis that by integrating engineering ethics into the design project, it would be more valued by the students and not perceived as an "add-on" to the core of the course. Our goal was to show students that ethical decision making is common in engineering practice, especially in sustainability related contexts, and we believe our integrated activities in the Fall of 2022 were an improvement over the Fall 2021 course offering in this regard.

One final perspective is from the teaching team faculty - five of the total eight faculty members who taught the course, not including the three co-coordinators who are the authors of this paper. While no official survey was distributed, feedback from bi-weekly teaching team meetings and end-of semester wrap-up meetings was overwhelmingly positive regarding the new iteration of ethics content. Integration into the engineering design process and a more detailed, interconnected set of individual assignments that addressed the three pillars of sustainability were specific improvements noted by faculty. In fact, further integration of ethics into each specific design project was one possible area of refinement for future course iterations.

**Conclusion and Future Considerations**

This paper presents an approach to integrating engineering ethics in a first-year interdisciplinary design course with an overall course theme of sustainability on campus. Ethics content included a range of activities and lessons, including class discussions, a team-based ethics simulation and written case studies and focused on considerations for the three pillars of sustainability (environmental, economic, and social). Overall, our results suggest that integrating engineering ethics into the engineering design process led to similar levels of self-reported learning for students and likely led to a greater sense of value for engineering ethics among students and a sense of more authenticity among faculty. Further work to probe the role of team-based learning in ethics and the balance between content repetition and extensions of ethical decision making to new topics may benefit future student learning.

**Supplementary Materials**

The ethics assignments described in this paper can be found in the following Google Drive folder - https://drive.google.com/drive/folders/14q-HK6KqyO42YLJRaavEDMKlNRe35XM5

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