Building Better Worlds: An Interdisciplinary Approach to Engineering Ethics Pedagogy

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Abstract: This paper, titled “Building Better Worlds: An Interdisciplinary Approach to Teaching Engineering Ethics,” is a work-in-progress empirical assessment of the value of a multimodal, interdisciplinary approach for ethics training and development. The paper, which describes a freshman seminar titled “GESM 121: Science, Literature, and Ethics,” commences with a review of relevant literature in ethics pedagogy. Survey data from students demonstrates the success of this unique and innovative approach. Students were surveyed about their experience in taking the course and their own assessment of levels of success in ethics training. Students from multiple terms were surveyed, to assess the consistency of success in using this non-traditional, interdisciplinary approach. Pedagogical methods (used both within the classroom and without) are discussed in detail in the paper. Course content is also discussed, with emphasis on the multifaceted nature of the curriculum: classical and contemporary ethical theory, readings in the philosophy of technology, and readings in diverse canonical and non-canonical works of science fiction. This humanistic course concluded with a summative group project, which required students to draw upon all aspects of the diverse curriculum in order to fulfill assignment goals. The project, which was designed to activate both creative and critical thinking abilities, directed students to create utopian societies. In order to imagine visionary alternative societies, students employed ethical principles, invoked themes and ideas from literature, and utilized new and even speculative technologies. In designing planned "perfect" communities, the students examined our most pressing social, scientific, and cultural challenges, responding to these problems by envisioning new possibilities in all areas of human life. The utopias were a blue-sky project; students were constrained only by the limits of their imagination and their understanding of course concepts. The summative project is a key example of the alternative learning methodologies employed in this seminar, and the paper describes in depth how students fulfilled assignment goals, using examples from student projects. This paper illustrates the benefits of employing a humanities-based approach when teaching engineering ethics.

Introduction

Since the adoption of the ABET EC 2000, ethics education in engineering has developed to a great degree. The revised ABET criteria cited a need for students to achieve an “understanding of professional and ethical responsibility [1, 2].” When we consider that only two decades ago most engineers graduated with little or no ethics education whatsoever, it is fair to say that dramatic gains have been made in increasing student comprehension of their ethical responsibility [3]. In 2016, the National Academy of Engineering examined exemplary ethics training models, and a quick perusal of the list demonstrates how the field has grown: Duke offers a Master’s degree in ethics education, MIT teaches a semester-long ethics course for freshman engineering students, and Northeastern University offers a multi-year study in ethics. Stanford has taken a broader and more hands-on approach, engaging students in community-based good works programs in

countries around the world. [4] Given this information, it seems that holding a rosy outlook on the future of ethics in engineering is quite reasonable.

However, we must temper such optimism with an awareness that the ethical issues posed by the scientific and technological advances of the 21st century are more pressing, more complex, and more immediate than in any previous era. As technology grows more and more embedded in every aspect of daily life, the need for future engineers to understand their role—and responsibility—in shaping society exponentially expands. The necessity for a "critical awareness of the way technology affects society and the way social forces in turn affect the evolution of technology" has never been greater [5]. In other words, efforts must be redoubled not only to expand the *number* of programs teaching ethics to engineers but to expand the *ways* that ethics in engineering are taught.

Literature Review

In their comprehensive study of ethics engineering education, Colby and Sullivan offer a survey of the most common modalities: case-based study deployed in modules, homework, and in-class activities; courses offered by philosophy departments in classical ethical theory; individualized class sessions examining codes of ethics, and professional responsibility embedded within applied engineering courses [6]. To this list, we can add other familiar models of ethics education, such as role-playing, stakeholder analysis, and less commonly, standalone courses in engineering ethics.

All of these pedagogical models have merit, but it can be argued that they tend to emphasize the role of ethics in the life of the individual engineer rather than the ethical implications of engineering as a profession, as a force that shapes and affects society. Given the role of technology in the modern world, it is crucial to bear in mind Herkert's distinction between "microethics" and "macroethics." [3] Macroethics, as Herkert defines it, is the study of the ethics of the profession of engineering, of engineers as a whole. It seems self-evident that we must include the macroethical view in ethics education, but this view is difficult to emphasize in certain pedagogical modalities. Many ethics pedagogies focus on the role of the individual engineer, particularly case studies that analyze issues such as cost versus safety, the responsibility of whistleblowers, as well as basic ethical guidelines such as refusing bribes and communicating honestly with peers, clients, regulators, and managers, among others. Case studies are of course crucial in to helping students learn how to apply ethical principles and professional codes to a specific set of events, but they do not lend themselves to a broader discussion of the role of technology in society.

In addition to the pressing need for an understanding of how engineering is determining the shape of our technological (thus also social and cultural) future, Herkert's singular, yet crucial, distinction points to another important issue in ethics engineering education: the lack of clarity about what types of ethics education are most effective. In his review of ethics education program, Hess and Fore note that "there is neither a consensus throughout the engineering education community regarding which strategies are most effective towards which ends, nor which ends are most important. [7]" Bairaktarova and Woodcock assert "that engineering educators struggle with is how to best accomplish this goal," and, in a historical review of ethics in engineering, Perlman and Varma note the lack of agreement on how ethics education should

be performed, noting that classes solely focused on ethical theory are not likely to be sufficient in preparing engineers for real-world ethical dilemmas. [8, 9] Colby and Sullivan also note the lack of consistency in methods of teaching ethics. [6] Shuman *et al* add important inquiries about content, methods, pedagogical methods, and curricula, raising the overall question of efficacy [10]. We do not know what works best among a multiplicity of models, such as standalone courses in ethics in engineering, adding ethics training to classes in applied science and technology, or attempting to increase humanities education in engineering. Concerns also exist about reliable assessment models for ethics education and, perhaps, most importantly, the question of whether or not ethics education can actually lead to ethical decision-making later in life. [9,11] Shuman adds the critical point that the ABET criteria asks only that students *understand* the need for ethical awareness, rather than that students must exhibit the ability to *resolve* ethical quandaries. [10] Can students, given the most common modes of education in ethics, develop a sense of what Edmund Burke called the "moral imagination"? And how would we know if they did?

The lack of consensus about best practices in ethics education, coupled with a sense of heightened need in current times, could reasonably seem like cause for potential concern, if not alarm. But it can also be argued that a lack of consensus offers an opportunity for experimentation and exploration. This uncertainty presents an opportunity to try alternative approaches, particularly approaches that emphasize creativity and interdisciplinary study. It has been argued that an interdisciplinary approach may be efficacious in the study of ethics, as interdisciplinarity offers a multiplicity of benefits that seem to have strong application to ethics, including but not limited to an emphasis on complexity, enhanced critical thinking skills, and an increased ability to make connections across disciplines. [12] Interdisciplinarity may also offer the invaluable benefit of making students more aware of internalized biases and prejudice, an awareness that seems keenly apt in ethics education. [12]

Interdisciplinary methods of teaching have been recognized as effective for both a multiplicity of reasons and a host of different kinds of topics. We will begin by defining the term "interdisciplinary," utilizing the commonly cited definition offered by Klein and Newell: it is "a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession," and it "draws on disciplinary perspectives and integrates their insights through construction of a more comprehensive perspective." [11] Newell writes, "Interdisciplinarity is necessitated by complexity," offering the example of a linked examination of acid rain, rapid population growth and Benjamin Franklin's autobiography. [12] Repko and Szostak, recognized leaders in the field, explain that "Interdisciplinarity complexity theory states that interdisciplinary study is necessitated when the problem or question is multifaceted. [13]" Bransford *et al* emphasize that interdisciplinary study grants students an increased ability to recognize preconceived biases and consider alternative viewpoints—an extremely powerful tool when working with ethics [14]. Research also demonstrates that interdisciplinarity enhances comfort with ambiguity and improves critical thinking.
[12, 13] Because interdisciplinarity emphasizes integration, it aids in the development of creativity: rather than focusing on fixed phenomena within a discipline, interdisciplinarity encourages students to make connections between distinct disciplines. With a focus on connection-building, as opposed to knowledge acquisition of specific disciplinary skills and

practices, students are pushed to think creatively. Interdisciplinarity encourages interrogation, as students cognitively register a range of types of knowledge, naturally comparing and contrasting as they are exposed to disparate fields of study. Ethics is a natural choice for the application of interdisciplinary study, because the questioning of boundaries is inherent in multimodal pedagogy. The examination of both empirical data and processes is key to this kind of study: in other words, students learn how to cycle between "declarative knowledge (factual information)" and "procedural knowledge (process-based information). [13]" (Experts in the field make key distinctions between the terms "multidisciplinary," "transdisciplinary," and "interdisciplinary," but this paper will not explore these valuable questions.) Research emphasizes the role of "collaborative practice" in interdisciplinary learning and student perspectives –such as preconceived ideas or internalized biases—may be strategically challenged by interdisciplinary study. [15] Furthermore, the literature underscores the tendency of interdisciplinarity to enhance the understanding of "higher-order relationships and organizing principles" as well as problem-solving skills. [13]

The use of an interdisciplinary approach to teach ethics in engineering is not revolutionary, and others have certainly employed it successfully in the past. [16] The skills embraced by interdisciplinarity as learning objectives clearly cross over with the objectives in ethics education. Among the steps that Allan Repko identifies as being part of interdisciplinary research/learning process are identifying the issue under examination, determining related disciplines, reaching proficiency in those fields, and most crucially, finding commonalities between disciplines and "[integrating] insights. [13]" When we examine the skills that are used in ethical decision-making, we can see a clear cross-over: Miner and Petocz list "perceiving, knowing, believing, remembering" as intellectual capacities. [17] Doing ethics is, by its very nature, an interdisciplinary process, through which individuals must identify key questions, consider both known and unknown data and consequences, and attempt to find a fair and reasonable resolution, by seeking advice from others, thinking through moral principles, and searching for insight through the gathering of different types of information.

Description of the Course

Consistent with the idea that ethics is inherently an interdisciplinary field, a course has been developed that attempted to integrate disparate fields. The syllabus is designed with the key objective of pairing readings in ethical theory with readings in literature (primarily science fiction, speculative literature, and dystopian fiction), and using those texts as lenses through which to consider contemporary controversies in Science and Technology Studies (STS). The primary goal of the course is to enable students to make connections between literature, philosophy, and STS. The question of whether or not reading literature can make one "more moral" is by nature a subjective one, but its benefits in increasing cognitive awareness, deepening empathy, and enhancing the ability to hold disparate "knowledge streams" at once are recognized. [18]

The approach taken in the course, GESM 121 "Science, Literature and Ethics: Understanding the Monster of Change," combines readings in ethical theory with canonical and non-canonical readings in science fiction and speculative literature. Principles drawn from

ethical theory and the science of philosophy are utilized in literary analysis, creating the first level of interdisciplinarity, pushing students to make connections between abstract philosophical concepts and specific themes, situations, characters, and narrative events. A further level of interdisciplinary study is added, wherein students apply course readings to current controversies in science and technology. Students post written responses to a discussion board each week, examining connections between fiction and ethics. In-class discussion further deepens such examinations.

The course challenges received notions and beliefs often held by students, such as the idea that progress is always good, that technology is neutral and purely instrumental, or that science is inherently good. The course begins with readings in classical ethics by Kant, Mill, and Aristotle; these readings are paired with canonical works such as Shelley's *Frankenstein* and Huxley's *Brave New World.* After the students build a knowledge base in classical ethics, more contemporary readings in ethics are introduced, such as John Rawls, Nel Noddings, Martha Nussbaum, Peter Singer, and Nick Bostrom. Readings in the philosophy of technology also appear in the second half of the course, with Hans Jonas, Langdon Winner, and Andrew Feenberg as touchstones. Literary readings also become more contemporary and more diverse as the semester progresses: Margaret Atwood's *Oryx and Crake*, Octavia Butler's *Lilith's Brood*, Kazuo Ishiguro's *Never Let Me Go,* and Ted Chiang's *The Lifecycle of Software Objects* round out the reading list.

In each class session, one student gives a research-based oral presentation on a specific topic in science and technology, using ethical principles and literary themes as lenses through which to assess and evaluate relative harms and benefits. Students choose their own subjects, thus presentations have been made on a wide variety of controversial topics, including genetic engineering, chimeras, autonomous cars, drones, de-extinction, the Internet of Things, social media, artificial superintelligence, cloning, GMO's, and facial recognition, to name only a few. These student presentations ground the course in contemporary ethical debates in science and emerging technology, and both expose students to new topics and allow them to think more deeply about such topics.

Students write an essay in which they again combine these disparate fields; the essay is essentially an outgrowth of their oral presentations. The essay must be thesis-driven, in which students use their newly acquired skills in ethical problemsolving to analyze a current topic of their choice. The essay also requires them to link their topic to themes and motifs in a single reading in literature, adding a further dimension of interdisciplinary study. Thus, to complete the essay, students must cycle between factual information (a description of known data about their topic in science and technology) and procedural knowledge (using ethical decisionmaking skills in a process-based fashion) to reach new conclusions.

The course culminates in a summative blue-sky group project that students work on over the course of the semester. In this collaborative effort, student create utopias: planned communities that are built around specific ethical principles, utilizing new technologies and incorporating themes from literature. This is a multimodal project, where students are required to write first a mission statement and then a constitution, in which the primary principles of their perfect worlds are detailed. Students also must consider a host of critical factors: where will their community be located? What are the goals of the community? How will the residents govern themselves, live,

eat, work, learn, and coexist in harmony? This creative project requires students to apply the skills they have learned, which is an attempt to respond to Herkert's critique that ethics courses in engineering often fail to consider the macro-level. It is also an attempt to respond to the suggestion that a "combination of methods" in ethics education may be more successful than a singular approach.

The utopia project forces students to think about which social problems they find to be most pressing and most harmful; they then respond to these social issues by finding solutions in the ethical concepts and literary themes and in new and emerging technologies. As this is a blue-sky project, students are permitted to engage in fantastical solutions, such as colonies on Mars, general artificial intelligence, human cloning, and genetic engineering. To complete the project, students must present the utopia orally, create original graphics, and write a 15-20 page report detailing as many aspects of their perfect world as possible. Reports must include citations and concrete references to both course readings and outside research.

Sample Utopia Projects

Projects have responded to a wide variety of social issues, including prejudice in all forms, poverty, inequities in education, failures of the health care system, and climate change. Figure 1 is an image of a community called "Harmonia," which aims to bring residents back into harmony with nature, de-emphasizing the role of technology and encouraging residents to grow their own food.

Figure 1: Harmonia

Students in a project titled “Antiskyju,” (students put their first names together to create a shared project title), worked to build a utopian city where all low-skilled labor is handled by automation and residents are funded via universal basic income. In this utopia, students were attempting to respond to the Rawlsian problems of widespread social inequity. The primary of this project was to build a city where all denizens were freed to pursue their passions, whilst residing together in a clean, cosmopolitan city, that promoted community and collaboration. (See Figure 2)

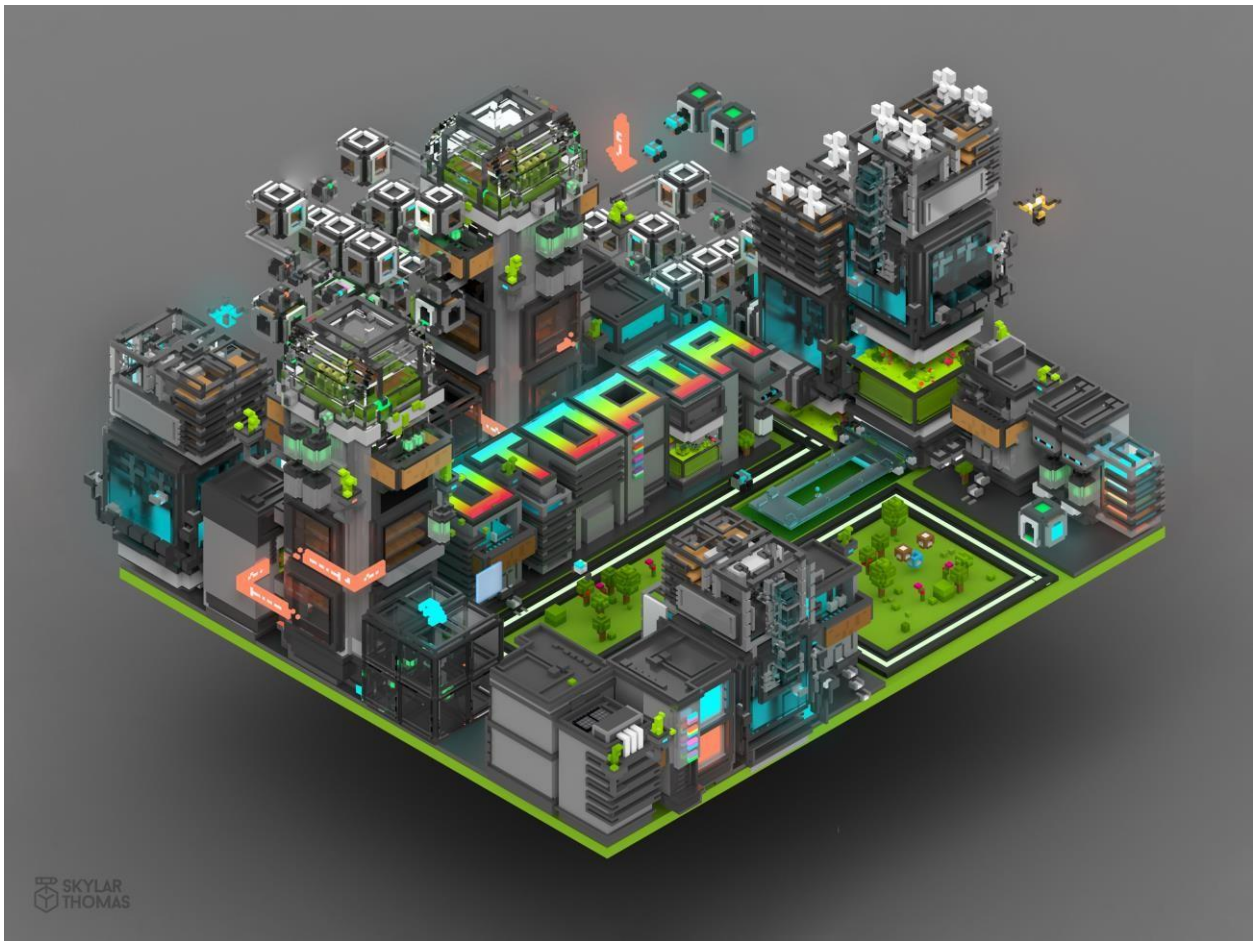
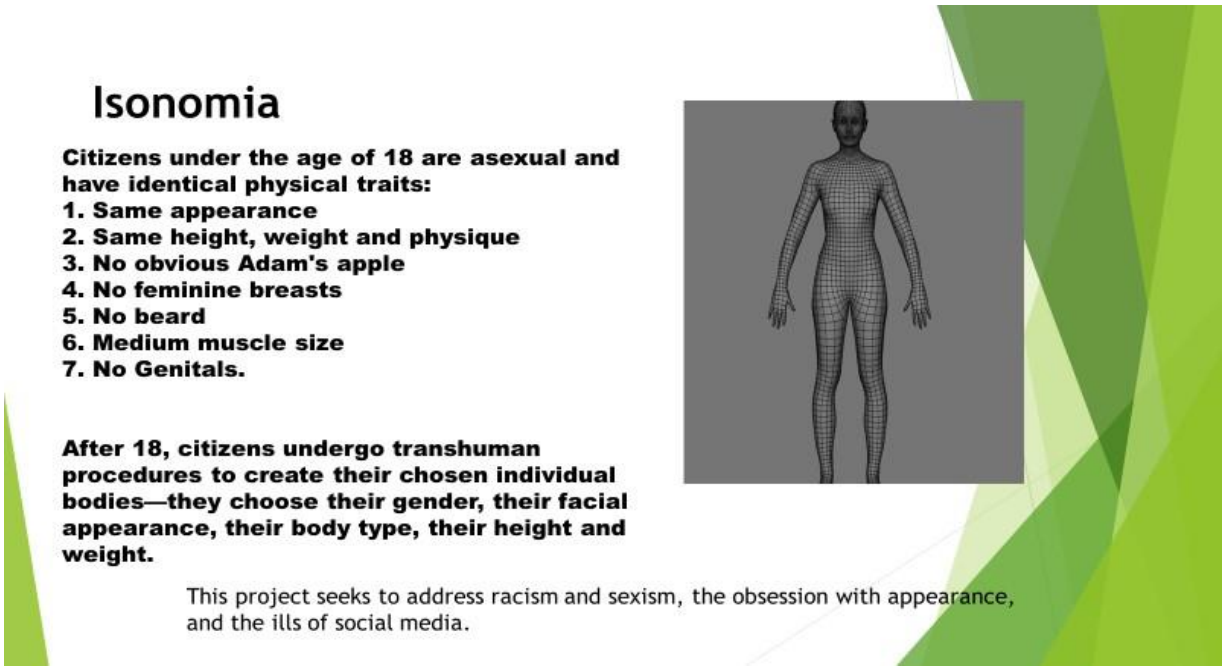


Figure 2: Antiskyju

The third example included here is an image from a project where students sought a solution to discrimination via an improbable but thought-provoking premise: in their utopia, Isonomia, all residents are identical until the age of 18. This example demonstrates how readings in science fiction evoke creative problem-solving, allowing students to use their imaginations, inventing fictional solutions to very real problems. In this imaginary world, children and young adults would be free from real-world pressures about appearance and unrealistic norms for beauty. (See Figure 3.) Students who worked on this project were inspired by readings in transhumanism, embracing transhuman ideals of moving beyond the limitations of our current physical bodies and current available technologies.



Caring Island (see Figure 4) is a utopian island paradise, where students incorporated concepts from feminist ethics in an attempt to redress failures in health care. In this planned community, all residents are either caregivers or patients; to use Noddings' terms, all residents are either "ones-caring" or "the cared-for." Students imagine a place where individuals with chronic or incurable illnesses, who have been failed by the health care system, seek refuge in a place where all their needs will be met. Similarly, caregivers, such as physicians, nurses, therapists and medical or biological researchers, find a place where their efforts to aid those in need of care are not hampered by real-world limitations in time and resources.

Figure 4: Caring Island

Analysis of Data

As mentioned earlier, the literature reflects the difficulties in identifying reliable assessment tools for ethics education. [7, 8] A mixed methods approach has been employed to gather data about student self-assessment of course efficacy overall and of individual aspects of the course. Students answered survey questions, in addition to filling out freeform comments. Feedback was solicited from former students in GESM 121: Science, Literature and Ethics at a major research university in California to form the basis for an assessment of the effectiveness of a freshman-level interdisciplinary course in ethics and science. Student feedback is drawn from a cohort of students who completed GESM 121. Of all students surveyed, 76% responded to the survey. The survey was administered to all students who have taken the course, which covers six semesters from Spring 2017 to Fall 2019. All students are in their first year of university.

It goes without saying that any survey of student' learning acquisition in ethics cannot reliably predict how students may react to real-world ethical dilemmas in the future; this survey attempts only to assess student evaluation of their own sense of development in the area of ethics. A primary future goal of this work-inprogress is to develop some assessment instruments of ethics comprehension to accompany self-reported data. In the next iteration of the course, students will experience some case-based study in contrast to other modalities used throughout the course; student understanding of ethical principles will be assessed immediately after case analysis. The same assessment instrument will be employed after an in-class discussion of a work of literature

via the lens of the same ethical principles, permitting a more objective demonstration of skill acquisition.

Furthermore, it should also be noted that this course is offered as general education course to freshmen in all disciplines, thus while a statistically significant number of students who took the course are enrolled in STEM-related fields, many current and former students are pursuing non-engineering related courses of study. (62% of students were enrolled in STEM related fields.) Rather than a limitation, the mixture of engineering and non-engineering students permits increased possibilities for creative thinking and ethical decision-making. The collaborative efforts of students from a variety of disciplines contributes to a multiplicity of skills available, particularly when working on the final project.

The survey was made available to all students who ever took the course, including current and former students. 81.49% of all students surveyed reported having an average or below average understanding of ethics as it relates to science; when asked how they would evaluate their mastery of ethics after taking the course,
75.29% reported that they felt they had retained either a "great deal" or "a lot" of knowledge accumulated in the course.

Students were also surveyed about their reaction to the interdisciplinary nature of the course: 55.56% strongly agreed that interdisciplinarity aided in knowledge acquisition, while 38.99% agreed. Of the STEM students who took the course, 69% felt that interdisciplinarity was extremely helpful in increasing their capacity to understand course concepts. No student felt that interdisciplinarity detracted from or decreased the efficacy of ethics education.

Responses to survey questions about the efficacy of using literature as a method to teach ethics overwhelmingly demonstrated a consensus that reading science fiction enhanced their understanding of ethics: 75.92% felt that reading novels and short stories helped them deepen their understanding either "a lot" or "a great deal." (See A majority of students also agreed that class discussions contributed to their mastery: 66% felt strongly that class discussion was among the most useful aspects of the class. The survey also allowed for open commentary on student reaction to the course: students felt strongly that the application of ethics to literature allowed them to better understand abstruse theoretical principles. Students also commented on their feelings about readings in philosophy, calling them "difficult," "dense," "long," "wordy," and "boring." However, even the students who reported the most negative reactions to primary source readings believed that the pairing of philosophy with other types of learning modalities helped them to better connect and comprehend readings in theory.

Student reaction to the creative project was somewhat mixed, though generally positive: 53.7% of students felt that the final project aided in deepening knowledge acquisition.

In the comments section, several students noted that the utopia project allowed them to directly apply the skills they had gained in. One student remarked that having had past experience with case-based ethics education, they felt that the creative project "was a much more useful way to understand ethics, because it pushed us to actually think about how ethics affects social problems in the real world." This finding is notable, because it reflects Herkerts' emphasis that ethics in engineering should be focused not only on the micro-level, but also on the macro, pushing future

professional engineers to consider the large-scale social implications of emerging technologies and designs.

One of the most encouraging pieces of data was found when students were asked about how the course had affected them on a personal level, with over 90% responding that they had had experiences in which the principles they learned in the course could be applied to their daily lives. (See figure 5.)

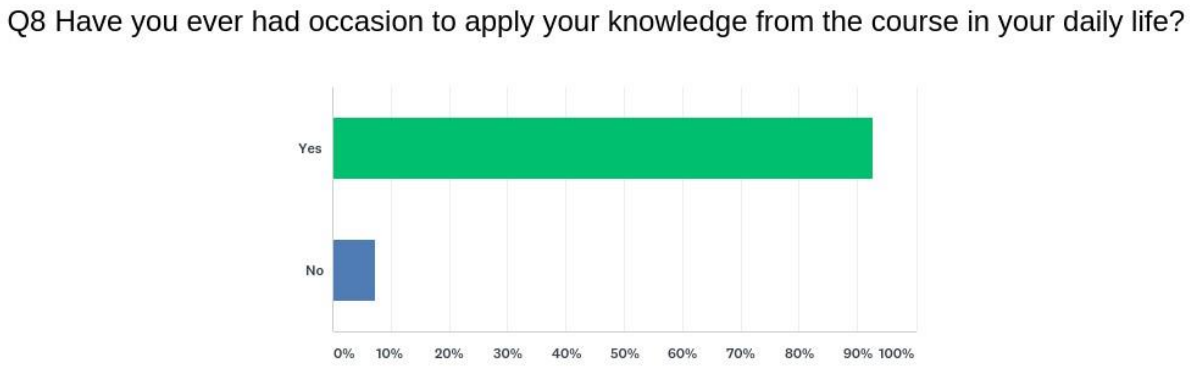


Figure 5: Using ethics in daily life

A survey was also conducted with a single class, with learning acquisition levels tested at the midpoint of the term and then after the completion of the course. When surveyed at the midterm about their exposure to ethics education prior to the course, 73.33% of students expressed having either “little” or “none.” When then questioned about their sense of improvement in an understanding of ethical theory, nearly 88% expressed having an above-average understanding, with the remaining 12% reporting an average understanding.

The students take one midterm and one final in this course, and those testing instruments clearly demonstrate an increased understanding in ethics by the end of the course. The average midterm grade for all students over all six semesters of the course is a B. But marked improvement is shown by the end of the term, with students achieving an average grade of B+ on the final. 34% of all students received an A-level grade on the final exam.

Conclusion

The findings of the survey demonstrate that students felt positively overall about how the course increased their sense of knowledge acquisition with relation to ethics in science and technology. The results overall support an ongoing effort to teach ethics via an interdisciplinary approach. The sample student papers, along with the survey data, reveal the possibilities posed by a humanities-based approach to teaching ethics in engineering. The creative final project also offers evidence that the implementation of an alternative approach to teaching engineering ethics offers an opportunity for students to attempt to apply skills in ethics, and may potentially offer a way forward to offer pedagogical methods that can more deeply inculcate an understanding of ethics, and perhaps, the possibility of influencing future ethical behavior.

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