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Teaching Engineering Ethics Using a Model from Public Health

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CONTEXT

Teaching of ethics extends beyond learning and applying a Code in the direction of developing good judgement with application to policy. An ethical framework from the Bioethics Institute at Johns Hopkins University was developed for making decisions regarding opening society in response to the COVID-19 pandemic and was used here. It has the following steps: identifying and assessing the feasibility of the policy, identifying four broad moral values – well-being, liberty, justice, and legitimacy, assessing how the policy promotes or weakens these values, considering and mitigating the negative effects of the policy, and making an "all-things-considered" judgment.

PURPOSE

Describe and analyse the use of a public health framework in teaching ethical development to engineering students.

APPROACH

Students in a year-four environmental engineering course were asked in 2021 to read a framework analysis for policy makers regarding opening society in response to the COVID-19 pandemic. The framework focuses on well-being, liberty, justice (including equity), and legitimacy. Students evaluated the university's COVID-19 policy for the semester and developed an alternative health and safety plan. Later in the year, the same groups of students (without an explicit mention of the earlier assignment) were asked to discuss the societal benefits of their semester-long design project for a water treatment plant. Students in 2023 did not use the framework with a more traditional teaching of ethics and development of health & safety plans, although they did conduct the same design project later in the year. This situation allows for reflection on the impact of the of framework both immediately and in terms of deeper learning.

OUTCOMES

Students were receptive to the use of the framework, engaged strongly, and were able to better assess the impacts of a proposed health and safety policy through its use. However, neither year's class showed clear evidence of internalising this development of ethical judgment unprompted in the later design project.

CONCLUSIONS

The approach provided students with a context to evaluate engineering decisions and make recommendations, along with a framework from which to consider tradeoffs, and develop engineering judgment. Additional educational support is needed to better internalise this development process.

KEYWORDS

Code of ethics, ethical education, formation of good judgement

INTRODUCTION

Engineering ethics is a critically important aspect of the civil and environmental engineering curriculum. The US engineering accreditation body, ABET, has included ethics as part of the general criteria for engineering programmes, namely in Student Outcome 4: "an ability to recognise 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". Furthermore, the ABET Programme Criteria for civil engineering mandates that the "curriculum must include the application of "an engineering code of ethics to ethical dilemmas", along with "principals of sustainability, diversity, equity, and inclusion to civil engineering problems". Similarly, Engineering New Zealand requires graduates to "apply ethical principles and commit to professional ethics and norms of engineering practice".

The pre-2020 American Society of Civil Engineers (ASCE), along with the current National Society of Professional Engineers, Codes of Ethics primarily focus on the individual, for example, with the requirement that engineers "issue public statements only in an objective and truthful manner" and "build their professional reputation on the merit of their services". In 2020, the American Society of Civil Engineers (ASCE) made a significant shift in its code of ethics, moving from a set of eight fundamental canons to a list of 36 responsibilities to five stakeholders: society, natural and built environment, profession, clients and employers, and peers. This shift in focus from the micro-level to the macro-level, emphasising society and the common good, underscores the evolving landscape of engineering ethics (Rodriguez-Nikl & Schaff, 2023). This shift from the micro-level, focusing on the individual, to the macro-level, focusing on society and the common good, marks a significant evolution in our field. However, Davis proposes that engineers act predominately at the meso-level; that is, they make ethical decisions within the framework of the organisation in which they work and belong (Davis, 2010). On the contrary, Vesilind (2002) and Gunn and Vesilind (2002) argue that engineers have a moral and ethical responsibility to act on the macro-level to protect the environment for its intrinsic value and future generations. This implies teaching of ethics that goes beyond learning and applying a Code and more that the "goal of teaching ethics is to make students familiar with certain activities in a way that these activities become *ethoi*" (Ferdman & Ratti, 2024); that is, part of their moral nature or guiding principles.

These two viewpoints on the expectations for engineering ethics education are not necessarily in conflict; however, with a packed curriculum creating an incentive to limit the teaching of ethics to what is seen as a minimum requirement, the two viewpoints often come into tension. Nowhere is this tension greater than in the teaching of civil and environmental engineering. Environmental engineering, in particular, has a central focus on environmental protection and an ethic of sustainability. Civil engineering education can often expect high levels of education on both aspects of ethics. Public consultation and participation are important aspects of the work of both civil and environmental engineering (Avendano-Uribe *et al.*, 2022; Glover & Hendricks-Sturrup, 2022; Wareham *et al.*, 2006) and would be clearly an area where both aspects of engineering ethics education would be expected to be taught at university.

PURPOSE

While engineering ethics is an integral part of engineering education, it is often relegated to a case study or two in a single course. Even when ethics is included in a course, Ferdman and Ratti found that the learning goals and outcomes of ethics modules are often unclear or lacking (Ferdman & Ratti, 2024). As mentioned earlier, ABET Student Outcome 4 (SO4) states that students must have: "an ability to recognise ethical and professional responsibilities". While many of the other student outcomes are written to achieve a higher level in the cognitive process according to what is commonly referred to as Bloom's Taxonomy (Anderson & Krathwohl, 2001), it is somewhat ironic that ABET assigns this outcome to the lowest level even though engineering ethics concepts are "messy", vague, ambiguous, and include uncertainty (Harris Jr *et al.*, 1996).

Some faculty members are reticent to teach engineering ethics because they believe they lack expertise and competence in the area of ethics, or they perceive the need to cover "hard-core" engineering content over "soft" topics, such as ethics. Chen and colleagues reported that requirements by some agencies for principal investigators (typically tenure-stream faculty members) to complete ethical training may convey that such training is merely an obstacle to overcome (Chen *et al.*, 2021). In many cases, the same is true for ABET student outcomes related to ethics.

This work describes and analyses one approach to teaching ethical development. It employs a framework to analyse a current issue with an endpoint regarding a policy. The issue of policy for COVID-19 re-opening was thought-rich for developing ethical judgement needed by engineers and to move the analysis from a micro-level to a meso-level where students think on a political dimension, which considers "what we all together as members of a community owe other members of the community".

This analysis discusses the use of a framework developed by the public health community to reopen facilities after the COVID-19 shutdowns in a classroom setting, with the goal of helping students develop their ability to recognise and apply their ethical responsibilities as engineers. In addition, the analysis presented herein provides a preliminary look at the ability of students to apply ethical content learned in one situation to another without direct prompting.

APPROACH

In response to the challenges of the COVID-19 pandemic, Bernstein and colleagues (Bernstein *et al.*, 2020) prepared a working document to provide guidance to policymakers regarding reopening society. As noted by the authors, reopening is a process that cannot be based simply on science and economics but must involve ethically evaluating the impact of such decisions. The framework involves the following steps: identifying and assessing the feasibility of the policy, identifying four broad moral values – well-being, liberty, justice, and legitimacy; assessing how the policy promotes or weakens these values; considering and mitigating the negative effects of the policy and making an "all-things-considered" judgment regarding the policy.

As discussed by Bernstein and colleagues, ethical judgments are implicit in answering the questions mentioned above. As all decisions have morally significant costs, it Is imperative that students understand that costs will be viewed very differently depending on the stakeholder. Engaging in ethical analysis allows students to understand how these different viewpoints can cause disagreements between different stakeholders. Using this approach can empower the students to clearly communicate and rationalise their decisions to those who hold opposing views. By fostering transparency, ethical analysis can reveal alternative, potentially more agreeable, policy choices to those who initially objected to the primary policy.

Civil and environmental engineering students in the fourth-year design-intensive MSU course, ENE 483 Water and Wastewater Engineering, were asked to read the Bernstein document. This was tied to an assignment where each of the student teams were asked to develop a Health and Safety Plan, which was intended to "a) enforce our commitment to the health and safety of each member of this community; and b) provide safe operating procedures, guidelines, and practices, specific to all class operations. The ENE 483 Health and Safety Plan provides detailed instructions for classmates to assist them in their individual efforts to conduct ENE483 business in a safe and healthy manner consistent with current law, rule, and technology". Classroom operations included lectures, field trips, a tour of campus water-related infrastructure, and laboratory experiments.

The framework of the Bernstein document was presented during a lecture, along with the university's policy and an alternative policy. The official university policy was, "if you are feeling ill or have tested positive for COVID-19, you should self-isolate and avoid close contact with others. Face coverings must be worn properly at all times". The university also stated that face coverings must be non-medical grade, fit snugly against the side of one's face, and cover one's nose and mouth. There was no requirement to notify those who had been in contact with the infected individual. An alternative policy was proposed, in which the students were to inform the instructor when they tested positive for COVID-19 and were in class during the likely infectious period. Since COVID-19 is airborne, the instructor was to notify other students irrespective of their location in the classroom. The instructor would not identify the student. The uncertainty regarding the effects of the various policies was discussed.

Students were assigned to groups and asked to evaluate the university's and alternative policies and consider their effects on well-being, liberty, justice, and legitimacy. They were also asked to consider the distribution of benefits and burdens by the group. In a subsequent lecture, the students were tasked with using this methodology to incorporate their own policy into the Health and Safety Plan that each student team was tasked with preparing.

As the course was taught online in 2021, the students were assigned to nine break-out rooms in Zoom, with 5-6 students in each room. In 2022, the lecture was given in person, and students were assigned to groups of 5-6 students. In 2023, the ethics lecture was eliminated due to time constraints.

In all three years, in addition to the health and safety plan assignment, each team of ENE 483 students was required to complete a semester-long design project. In 2021 and 2023, the design project was focused on designing a new water treatment plant for Marshall, Michigan, where the construction of a lithium battery plant would result in a doubling of water consumption. In addition, the project proposal stated that the City of Marshall planned to build a new hospital, school, and a satellite university campus and that the groundwater source was insufficient to meet the new demand. As such, a new source of water (Kalamazoo River or Lake Michigan) would be necessary.

This set of experiences allows us to begin to consider how students apply ethical principles taught in early in the semester to work assigned in the latter part of the same semester in the same course. In 2021 and 2023, the design project was identical; however, ethics was not taught in 2023 using the Bernstein model unlike in 2021. This allows us to examine the qualitative differences in their project work and provides the foundation for future studies.

OUTCOMES

Analysis of COVID-19 policies

In Fall 2021, the ethics lecture was given in the regular 50-minute lecture, so time was not allotted for significant discussion within breakout rooms. In Fall 2022, the ethics lecture was given in the 110-minute tutorial timeslot, which allowed for significant time for discussion within the breakout rooms. Students were receptive to the framework's use. Using the framework the teams were able to assess the impacts of existing and proposed policies on factors such as public health, mental and physical well-being, privacy, and trust. They were also able to articulate the advantages and disadvantages of both policies, although they tended to focus on the more obvious effects. Interestingly, the responses regarding economics were quite cynical and focused on bringing in more money for the university. Students considered the impact of the policies on different populations, including older staff and faculty and younger siblings. They could also see how the impacts on freedom were mitigated by providing religious exemptions for vaccinations. Students articulated how reporting cases to one's instructors has positive aspects, such as reducing the caseload, and negative impacts, such as violating one's liberty. Students also related the policies to issues such as airborne transmission.

Health and Safety plans

Health and Safety Plans were written during the tutorial, where students were divided into ten teams. In 2021, students worked in Zoom breakout rooms, while in 2022, students worked in person in the classroom. Students were provided a basic health and safety plan with prompts for their discussion. The prompts included the request regarding communication, "make sure to think about the four basic moral values discussed".

In 2021, only two teams explicitly mentioned these four values. One of the ten teams provided a written analysis of their plan regarding COVID-19 precautions.

- Wellbeing: we as a whole are in agreement that we would like to upkeep our health and safety. In order to do so, we must work together to protect ourselves and the people around us by being conscientious of our actions and behaviour during this pandemic.
- Liberty: Out of our direct control. Different students/staff have different moral values, backgrounds, religions, and opinions. Those who practice religions that have moral exemptions from being vaccinated may take alternative steps (spit test) to ensure health and safety for themselves and others.
- Justice: includes a fair distribution of benefits and burdens. If the class can work together as a whole to stay safe and healthy we will all benefit. If students refuse to comply with safety guidelines, incidents are more likely to occur which would negatively impact everyone.
- Legitimacy: The safety guidelines put in place are regulated by the FDA and CDC guidelines. This ensures expert opinion and health provider knowledge are included in the safety plan.

Another team wrote, “In terms of ethics, communication is an important part of legitimacy. Any classroom policies or updates thereafter relating to COVID-19 prevention and safety will be communicated to every student in the class.”

In 2022, none of the students called out the four moral values specifically. However, six of the ten groups made some mention of moral values, in general, as shown below

- be respectful of morals, respect if they choose to/ not to wear a mask
- be responsible and considerate
- class votes on policy to ensure fairness
- be respectful to public well-being and communicate if exposed
- we can agree as a class to take individual responsibility
- we are in control of our own individual actions, not those of others. We can hold ourselves accountable by following testing procedures and masking when necessary.

In Fall 2023, as mentioned previously, the ethics lecture was not provided due to time constraints. As such, while the general health and safety plan template provided to the students was identical to the previous two years, reference to the four basic moral values were removed. However, the template still asked, “What is in our control? What are the actions that we could agree on as a class and act upon?” regarding the risk of infectious diseases.

Interestingly, in Fall 2023, of the 19 groups working on the same design project and a facility-specific Health and Safety Plan (but without the lecture and examination of the Bernstein method), none mentioned COVID-19 despite the prompt regarding infectious diseases. Where mention was made of microbial diseases, the comments pertained to transmission via insects and water.

None of the groups in 2023 mentioned moral values or ethical codes. Three of the 19 groups did mention how the group could work together to mitigate risks:

- We can agree to follow all necessary protocols and procedures to maintain a safe environment, and if someone is not following the correct procedures, we can correct them.
- The class can agree on a certain behaviour they should have when being out in the field for sampling or for the field trips or scavenger hunts the group will be on during the semester.
- Look out for your classmates

Water treatment plant design

In all Fall 2021 and 2023 semesters, the students were asked to address the societal benefits and the environmental benefits and challenges of the proposed treatment facility. This was worth 10% of the technical portion of their final design report.

Despite the presentation on ethics early in the semester in 2021, there were no significant differences between the team responses for the end-of-semester work for the Fall 2021 and Fall 2023 semesters, as shown in Table 1. Not surprisingly, the benefit mentioned by the greatest number of teams was “protecting public health”, which is consistent with the ASCE Code of Ethics.

Perhaps more surprisingly, about 25% of the teams in 2021 did not mention public health. All the students completing this course would have completed a CEE course focused on sustainability, yet only half of the teams mentioned sustainable development as a societal benefit. One team (2021) mentioned LEED certification. While the project proposal explicitly mentioned the construction of the lithium battery plant and the number of jobs, along with opening a new hospital and school, only 50-61% of the teams mentioned economic growth. The higher percentage was for Fall 2023, when more information was available on the battery plant, which may explain this result.

Table 2 lists some of the more interesting discussions. In both semesters, several of the student teams mentioned issues related to equity. In 2021, two of the teams discussed the importance of public trust in officials, which related back to the ethical discussion on legitimacy associated with Bernstein *et al.* (2020). Another included a complex discussion of opposing views and the need for the health and well-being of the residents of Marshall to be protected.

However, in 2023, four teams mentioned the importance of public trust. While the ethics lecture was omitted from the 2023 design course, Masten gave a guest lecture on ethics (as it relates to the Flint Water Crisis) in another fourth-year environmental engineering course about a week before the design report was due. Since there was a significant overlap in enrolment in the two courses, it is possible that that lecture influenced the thought process of students in the Fall 2023 water and wastewater design course.

Table 1 Comparison on student responses related to societal factors for later Drinking Water Plant design (2021 with earlier Bernstein framework, and 2023 without).

Societal benefits	Fall 2021 (20 teams)	Fall 2023 (18 teams)
Promotes economic growth	10	11
Promotes socio-economic growth	2	2
Prevents water scarcity/ water shortages	5	-
Protects public health	15	14
Promotes welfare	7	3
Incorporates sustainable development	10	10
Design is affordable/cost-effective	6	6
Involves public trust	2	5

Table 2 Comments from student teams related to societal benefits for later Drinking Water Plant design (2021 with earlier Bernstein framework, and 2023 without).

Comments related to societal benefits	Semester
The design would benefit economically disadvantaged residents as it is unlikely that they would be able to afford whole-house water treatment	Fall 2021
Improved water treatment would allow people to focus on higher goals like literacy and education	Fall 2021
We will work with local artists to create murals on the outside of the building that showcase different features of Marshall	Fall 2021
Improved disaster preparedness	Fall 2023
Since the community will have access to clean water, this will reduce the amount of plastic water bottles people buy and use in the city.	Fall 2023
Provide future recreational opportunities	Fall 2023
Improved health can also have additional societal impacts like school attendance and increased childhood survival	Fall 2023
Poor water quality has negative implications for impoverished individuals). This creates a cycle of poverty as productivity decreases and money must be spent on medical necessities. This possibility can be eliminated by ensuring treatment water is available to all citizens of Marshall. Therefore, positive health outcomes will allow for general socioeconomic improvements.	Fall 2023

CONCLUSIONS

Students engaged strongly with the examination of ethics through policy setting decisions related to COVID-19 mitigation strategies. They understood the material provided and could use this information to assess the impacts of their proposed policy. They were also able to use the framework when developing health and safety plans for classroom and related activities, as the health and safety plans were directly tied to the lecture. The teaching of ethics by focusing on developing policy is an approach that provides students with a context to evaluate engineering decisions and make recommendations. This approach is an important part of developing good ethical judgement.

When students evaluated policy decisions using this framework, their health and safety plans were more complex and complete relative to the year when they the framework was not presented. When taught with the framework, students included more detailed information about COVID-19 restrictions along with preventative measures for other hazards, such as commuting to campus and participation in field trips and laboratories.

However, it did not appear that the ethical discussions early in the semester influenced their analysis in their final design projects at the end of the same semester. The 2021 students, who had the benefit of focused content on ethical judgement demonstrated little carryover of their learning into the final analysis of the societal benefits of the water treatment plant design. There was essentially no difference in their analysis of the societal benefits as compared to the 2023 students who did not have the benefit of the ethics lecture and assignment. Neither set of students were specifically instructed to apply the ethics that they had learned earlier in the course to their final design project, although some students did introduce broader concepts into their design reports. Nevertheless, the lack of carryover was notable and disappointing. Although some demonstration of the formation of engineering judgement is better than none, we have identified a further challenge of having students internalise this formation to the point where they can apply it to new problems similar to how mathematics and chemistry are learned and then applied in very different problems without prompting.

This work is anecdotal in nature, with no pre-determined hypothesis regarding the effectiveness of teaching engineering ethics. It can still help others to refine their own teaching of ethics, and aid those who wish to develop future work with greater emphasis on hypotheses and controls. Future work could involve revising the Bernstein document so that it is more broadly applicable and less tied to reopening during the COVID-19 pandemic. The revised document could then be used to evaluate engineering decisions in a more systematic way that uses the four moral values. Finally, it would have been beneficial if the design project requirements specifically requested that students consider the impact of engineering solutions in a societal context using the four moral values.

ETHICAL APPROVAL

This study (STUDY00011077) was reviewed by the Office of Regulatory Affairs Human Research Protection Program Institutional Review Board at Michigan State University and was determined not to involve "human subjects" as defined by the Common Rule as codified in the U.S. Department of Health and Human Services (DHHS) regulations for the protection of human research subjects.

SUPPLEMENTAL INFORMATION

For supplemental information in the form of selected student responses, please contact the authors.

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