Integrating Ethics Across the Civil Engineering Curriculum

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Introduction

With the rapid advancement in technology, it is imperative that students think critically about ethics, particularly for civil engineers that work on public infrastructure and buildings. The recent failures with Flint, Michigan lead-contaminated drinking water, the pedestrian bridge collapse in Florida, VW emissions coverup, and others have highlighted the need for students to understand the overall implications of their actions or inaction. The American Society of Civil Engineers (ASCE) and National Academy of Engineering (NAE) code of ethics is a good place to start, but students are often only required to read and know the code and often do not understand that ethics in engineering is not always clear and simple\textsuperscript{1,2,3}. Many authors have called for improving ethics education in engineering, identifying a need to shift focus from the individual to social responsibility\textsuperscript{2,3,4,5,6}, to consider the conflict that can occur between multiple ethical issues and the impacts of failure\textsuperscript{1}, and grounding instruction in ethical theory\textsuperscript{7}.

Due to requirements of the Accreditation Board for Engineering and Technology (ABET), all ABET-accredited universities in the U.S. incorporate ethics into their curriculum in some way\textsuperscript{8}. The most common is to require students to take an ethics class, which is either taught in engineering or in a department outside of engineering\textsuperscript{1,3,5,7}. Many universities also “bookend” the curriculum by addressing ethics in a first-year introductory course and a capstone course taken right before graduation\textsuperscript{7,9}. However, the general consensus is that the most effective method for teaching ethics is integration of ethics throughout the curriculum, which compels students to recognize that ethics is an integral part of their engineering education\textsuperscript{3,9,10,11}. The importance of ethics is highlighted when students receive ethics instruction from several engineering professors, and professors coordinate their efforts\textsuperscript{11}. If ethics is taught as a part of technical engineering classes, students can also see the connection between the technical material traditionally taught in engineering classes and the ethical implications of design.

In addition to where ethics is taught in the civil engineering curriculum, the way ethics is taught and how students are assessed impact the quality of their ethics education. Case studies, class or group discussion, inclusion of ethics in design projects, theoretical grounding, and service learning have all been identified as effective modes of disseminating ethics\textsuperscript{12,7,10}. Assessment has also been identified as an important facet of ethics education, particularly formative assessment that occurs in the classroom\textsuperscript{12}. Many of these methods can be categorized as active learning, which has been shown to increase conceptual understanding and retention\textsuperscript{13,14,15,16}. Ethics education may improve if multiple methods of disseminating ethics, including active learning, are used throughout the civil engineering curriculum.

To improve understanding of the many ethical issues students may face as practicing engineers, we developed ethics modules in four civil engineering classes at the University of Portland (UP). Some modules involved active learning, whereas others were traditional writing assignments. As
a result, students receive some sort of ethics instruction at least one time per year throughout their four years at UP. This paper evaluates the effectiveness of integrating ethics across the civil engineering curriculum at UP using multiple learning methods.

Methodology

The ABET-accredited civil engineering program at University of Portland has a 4-year curriculum. The first year includes an introduction to engineering course, in addition to math and science courses. The second year includes the mechanics series (statics, dynamics, strengths of materials) and environmental engineering. The third year of the curriculum includes required courses in the other civil engineering subdisciplines (hydraulics, structural, geotechnical, transportation), and the fourth year includes a year-long capstone design course and civil engineering electives. Figure 1 shows the courses that already cover ethics, as well as the courses that were selected for adding ethics. These courses were selected to increase student exposure to ethical issues related to civil engineering, and to ensure ethics topics are distributed amongst the civil engineering subdisciplines. Instructor buy-in was also a factor.

![Figure 1. Progression of ethics instruction in UP Civil Engineering Program. White boxes indicate courses where ethics is already covered, and gray boxes indicate courses that were selected for adding ethics.](image)

As part of the core curriculum requirements at University of Portland, all students are required to take an ethics course in the Philosophy department (PHL 220). In this course, students receive an introduction to the major theories in classical and/or contemporary moral philosophy. Emphasis is placed on understanding and applying the theories of moral obligation including utilitarianism, deontology, social contract theory, ethics of care, natural law, and virtue theory. The course also covers relativism and absolutism. The ethics modules included in courses were designed so students could apply the ethical theories they learned in PHL 220 and the ASCE Code of Ethics to a case study or design project. Students were allowed to consider all ethical theories, but focused on the deontological, utilitarian, relational, and character theoretical frameworks. The following is a summary of each canon in the ASCE Code of Ethics:

1. Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.
2. Engineers shall perform services only in areas of their competence.
3. Engineers shall issue public statements only in an objective and truthful manner.
4. Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.
5. Engineers shall build their professional reputation on the merit of their services and shall
6. Engineers shall act in such a manner as to uphold and enhance the honor, integrity, and
dignity of the engineering profession and shall act with zero tolerance for bribery, fraud,
and corruption.
7. Engineers shall continue their professional development throughout their careers, and
shall provide opportunities for the professional development of those engineers under
their supervision.
8. Engineers shall, in all matters related to their profession, treat all persons fairly and
encourage equitable participation without regard to gender or gender identity, race,
national origin, ethnicity, religion, age, sexual orientation, disability, political affiliation,
or family, marital, or economic status.

Courses with Ethics Modules Already in Place. Two courses, EGR 110 Introduction to
Engineering and CE 483/484 Civil Engineering Capstone Design, already include ethics
modules. These courses are “bookends,” students receive ethics instruction in the fall of the first
year and the fall and spring of their last year. The existing ethics modules for these courses are
briefly described below.

EGR 110 Introduction to Engineering: In the first year, students learn about academic
integrity and the code of ethics in engineering in the Introduction to Engineering class. One class
period is devoted to a lecture on UP’s code of academic integrity, the consequences of violating
the code, the code of ethics in the engineering profession, and how academic and professional
codes are related. An additional class period is devoted to an activity where students discuss and
reflect on various scenarios of academic violations. These scenarios were intentionally written to
help students be aware of the intricacies of the academic code and how to avoid pitfalls, such as:

“You are working in the computer lab late in the evening on your laboratory report due the next
day. Your friend Hans is using the computer next to you and asks what you are working on. You
explain your lab report is due in the morning and Hans laughs and tells you that lab report took
him 3 hours to write when he took the same class last year. He offers to give you his old
laboratory report to help you finish up faster. You are exhausted from a long week of midterms
and desperate to finish the report. You agree to his offer immediately and plan to simply check
the conclusions to make sure you are on the right track. When you open the document you
realize that your calculations are completely wrong and you will need to start from scratch. In
desperation, you copy his calculations and parts of his lab write-up and turn it in the next day.”

Students are put into groups of 3-4, and asked to discuss the scenarios. The groups then report
out to the class.

CE 483/484 Civil Engineering Capstone Design: Civil engineering capstone design is a year-
long course where students work on a design project during their fourth year. Students have both
a faculty and industry advisor for the project, and explore many aspects of design. In the fall, the
ASCE Code of Ethics is reviewed and students complete a short written assignment to
familiarize themselves with the Code of Ethics. In the spring, students present and lead a short
class discussion on the ethical implications of their design project. Because each design project is
different, this could include the health and safety of working on a brownfield site, imminent
domain, stakeholder conflict, etc. Students were asked to identify which canons from the ASCE Code of Ethics and which ethical theories were applicable.

**CE 376 Environmental Engineering Laboratory.** In the second year, students take Introduction to Environmental Engineering, which includes a laboratory component. The ethics module was developed by first identifying several case studies involving environmental engineering. Recent case studies that have been in the news, such as the Flint, Michigan lead-contaminated drinking water and the VW emissions cover-up, were selected to increase student interest. A total of eight case studies were included: Flint, Michigan lead-contaminated drinking water, Nevada arsenic contamination, California injection wells, Navajo Reservation uranium-contaminated drinking water, Alberta tar sands, North Dakota oil line, Dimock, Pennsylvania Fracking, and VW emissions cover-up.

Students completed the module in their lab groups (typically 3-4 students per group). Students had to read about all case studies, but chose one to learn about in more detail. The module was designed to include active learning in the classroom; students conducted research on their chosen case study and led a class discussion of the case study. During the class discussion, students were required to briefly summarize the case study, and identify which canon(s) in the ASCE Code of Ethics was violated and which ethical theory was the most applicable. Students also discussed what could have been done to avoid ethics violations and what they may have done differently. Students were given an opportunity to develop their own discussion questions for the class discussion, but the following example discussion questions are provided:

1. What was the main event or action that caused this situation?
2. How do you think a civil engineer was involved?
3. What potentially did the civil engineer fail to do?
4. Does a civil engineer have the responsibly to do something for this situation? Explain.
5. What actions from those involved could have prevented the problem?
6. What were the responsible party's consequences (i.e. settlements, agreements, resignations, etc.)? Was the punishment(s) appropriate? Was justice served?
7. Is there more than one solution?

**CE 351 Structural Analysis.** To develop the ethics module associated with Structural Analysis, structural failure case studies with ethical issues were identified. Three case studies were chosen to conduct the assignment: the Oroville Dam and Spillway failure, the Algo Centre Mall failure, and the I-35W Mississippi River Bridge failure.

Students completed the ethics module in groups of five. Each group was assigned one of the case studies, which they conducted research on and then wrote a paper on the ethical implications. Students were required to address the following in the paper:

1. Describe the case study in detail. What happened? What led to the failure?
2. How does this case study qualify as an engineering ethical dilemma?
3. What ethical canons were followed, and which canons were violated? Discuss in depth.
4. What could the engineer have done to prevent this? How could the problem have been resolved before the failure?
5. What litigation occurred? How was the engineer dealt with after the failure, did he/she have any consequences?
6. How does this case study relate to you and your future work as a civil engineer?

Students were only required to complete the paper; there was no class activity or discussion associated with the ethics module.

**CE 315 Transportation Engineering.** In the Transportation Engineering class, students are assigned a design project that involves redesigning one of the campus parking lots. Students are required to address the social, economic, and safety aspects of their designs. The ethics module was integrated into the design project by requiring students to address at least one ethical component of the project and discuss how ethics impacted their design.

Students did research on several ethical issues that may impact the project, chose one to focus on and analyze, then wrote a paper summarizing the ethical issue and how it impacts their design project. At least one canon from the ASCE Code of Ethics and one ethical theory that applied to the project had to be identified. Students were only required to complete the paper; there was no class activity or discussion associated with the ethics module.

**CE 465 Open Channel Flow.** The ethics module for Open Channel Flow, which is a fourth year elective, was developed by first identifying a series of case studies of dam failures and proposed dams that were never built. Six case studies were identified for the module: the South Fork Dam Failure, the Hetch Hetchy/ O’Shaughnessy Dam, the St. Francis Dam Failure, the Auburn Dam Proposal, the Teton Dam failure, and the Oroville Dam Failure. These case studies were selected to promote an analysis of engineering ethics over time and across the country.

Each student was required to read about the case studies and answer questions about the general trends of the cases. These questions included the following:

1. How have societal views of dams changed over the last 100 years?
2. Why do you think this shift took place?
3. What are the short and long-term impacts of constructing and removing dams on the communities in those areas?
4. What impacts do dam failures have on the economy, environment, and energy use of the surrounding communities?
5. How did public perception change of the engineering profession?

These questions provided lenses through which the students could analyze a single case study.

The students were also asked to form groups of 3-4 to perform an in depth analysis of a single case of their choosing. The groups were asked to conduct research on their chosen case study beyond the information given in the assignment and give a five-minute presentation to the class. The presentation included an overview of the ethical implications of the case study and how ideas from the ASCE Code of Ethics and ethical theory were applicable. With the added information from the presentation the group then led a class discussion.
Post Assignment Survey. To assess the effectiveness of the new ethics modules, the students were given a survey in the four courses where ethics modules were implemented. The survey was given after the ethics module was completed. The first seven questions on the survey ask the student to rate their response to statements on a Likert scale from 1 to 5, with 1 strongly disagree and 5 strongly agree. These statements included:

1. Before this course, I knew the ASCE Code of Ethics very well.
2. My preparation for the case study overview and discussion improved my understanding of the ASCE Code of Ethics.
3. Class discussion improved my understanding of the ASCE Code of Ethics.
4. I can better recognize a situation that violates the ASCE Code of Ethics.
5. I believe I will apply what I learned about ethics in engineering in my professional career.
6. I think the Ethics Assignment was beneficial to my understanding of what is expected of a professional engineer.
7. The Ethics Assignment reinforced or improved my understanding of Ethical Theories from PHL 220.

To evaluate whether the results of the survey questions were statistically different between courses, the Kruskal-Wallis test was used. This test is nonparametric, and allows for comparison between two or more independent samples of equal or different sample sizes\textsuperscript{18}.

Students were also asked open-ended questions, including:

8. How many canons of the ASCE Code of Ethics would you claim to know well?
9. Describe a canon from the ASCE Code of Ethics
10. Provide a hypothetical example that demonstrates a violation of the canon you previously described
11. Provide a hypothetical solution to the violation you described
12. Comment on the ethics assignment. What did you like and what would you change or add?

Since question 8 was quantitative, the Kruskal-Wallis test was used to determine whether the difference in number of canons was significantly different between the courses. The remaining open-ended questions were analyzed for common themes, and used to determine what changes (if any) would improve the ethics modules.

Results and Discussion

As a result of this effort, ethics has been fully integrated into the civil engineering curriculum at UP. At the time of implementation, there were 34 students in the Environmental Engineering Lab, 26 students in Transportation Engineering, 23 students in Structural Analysis, and 19 students in Open Channel Flow. Not all students filled out the survey however; they were told that completing the survey was optional but would help the faculty improve the curriculum. As a result, 34/34 students in Environmental Engineering Lab, 8/26 students in Transportation Engineering, 23/29 students in Structural Analysis, and 18/19 students in Open Channel Flow filled out the survey. Low participation in Transportation Engineering may be due to the way the
survey was given; the survey was completed outside of class and returned during the next class period. In all other classes, students were given time in class to complete the survey and it was collected before the end of class.

Figure 1 shows student responses to questions 1-7, and Table 1 shows the percentage of students who either agreed or strongly agreed with the survey questions. Student responses to questions 1-6 were significantly different between classes (p<0.05), and statistically the same for question 7. Students thought their understanding of the ASCE Code of Ethics increased as a result of the ethics modules; average scores on questions 2-4 for all classes were above the neutral score of 3 and ranged from 3.30-4.22. Table 1 shows that most students agreed or strongly agreed with questions 2-4, except the students in Transportation Engineering. Only half the students agreed or strongly agreed with question 2, and 38% agreed or strongly agreed with question 4. Although average scores were above neutral in Transportation Engineering, this indicates that many students were either neutral or disagreed with questions 2-4. This may have been due to the nature of the assignment in Transportation Engineering; because they were only required to identify one canon they may not have learned much about the other 7 canons.

![Figure 2. Average student response to post assignment survey, with standard deviation. No data is shown for Transportation Engineering and Structural Analysis on question 3 since there was no class discussion in these courses.](image)
Table 1. Percentage of students who agreed or strongly agreed with each survey question. No data is shown for Transportation Engineering and Structural Analysis on question 3 since there was no class discussion in these courses.

<table>
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<th>Question</th>
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Students also believed the ethics modules were helpful in preparing for their professional careers (questions 5 and 6). Average scores ranged from 3.67-4.72 and the majority of students agreed or strongly agreed with these questions. Students in all classes were able to recognize the importance of understanding ethics as a professional engineer.

Students did not think they had a good understanding of the ASCE Code of Ethics before the ethics module (average scores ranged from 1.91-2.75, 6-38% of the students agreed or strongly agreed), except for students in the Open Channel Flow class (average score of 3.44, 61% of the students agreed or strongly agreed). This difference is likely due to the fourth year students also learning about the ASCE Code of Ethics in their Capstone Design Course. Many students also did not agree that there was a connection between ethical theories and the ethics modules (question 7). Average scores ranged from 2.89-3.26, and the majority of students disagreed or strongly disagreed with the question except students in the Environmental Engineering Lab where 72% of the students agreed or strongly agreed with the question. Although many students in the Environmental Engineering Lab agreed with question 7, results were statistically the same amongst classes.

Figure 3 shows the results of question 8. Student response to question 8 was significantly different between the classes (p<0.05). Students could identify the most ASCE Code of Ethics canons in Open Channel Flow, which is a fourth year course. More canons could be identified in Environmental Engineering Lab compared to Transportation Engineering and Structural Analysis, which may have been due to the different method of teaching the ethics module. In the Environmental Engineering Lab, students read all case studies and led a class discussion. As part of the discussion, they were required to identify the canons related to the case study. During the discussion, other students and the instructor had an opportunity to mention the canons the student group may have missed. In Transportation Engineering and Structural Analysis, there was no opportunity for formative feedback in the classroom. Other confounding factors, such as instructor, number of survey respondents, etc., could also be the reason for the difference. The same instructor taught the Environmental Engineering Lab and Open Channel Flow, and different instructors taught Transportation Engineering and Structural Analysis. In addition, only 31% and 79% of the students completed the survey in Transportation Engineering and Structural
Analysis, respectively, whereas 95% and 100% of the students completed the survey in Open Channel Flow and Environmental Engineering Lab, respectively.

All students could answer questions 9-11, where they were asked to name one canon from the ASCE Code of Ethics, an example violation of the canon, and a solution. However, some students named the first canon, “Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties” and provided a very simple safety example and solution. It did not appear these students understood the underlying complexities of ethics. Other students provided thoughtful, complex examples that illustrated their understanding of ethics.

Student comments on the ethics modules (question 12) were generally positive. Several students in the Environmental Engineering Lab and Open Channel Flow classes commented that they liked the class discussion, and students in the Structural Analysis class commented that they would like a class discussion/group presentation of the case studies so they can learn about ethical implications in other situations. Students in the Open Channel Flow class also commented that they liked thinking about multiple ethical standpoints, and they appreciated thinking about more than just numbers. In addition, they appreciated using both the ASCE Code of Ethics and ethical theories to analyze case studies.
Overall, the survey results indicate student level/year did not impact ethics understanding. Scores were consistently higher in the second year Environmental Engineering Lab course and the fourth year Open Channel Flow course than the third year courses (Transportation Engineering and Structural Analysis) for most survey questions. The main difference between these classes is the type of activities and assignments that were given; the Environmental Engineering Lab and Open Channel Flow ethics modules included class discussion where students could hear other perspectives and insights beyond their own. It also provided and opportunity for the instructor to provide formative feedback. The Transportation Engineering and Structural Analysis ethics modules were more traditional, written assignments. This is also supported by student comments. Although these assignments still positively impacted student understanding of ethics, the class discussion appears to strengthen that understanding.

Conclusions

As a result of this study, ethics has been successfully integrated into the CE curriculum at UP. Students learn about ethics in at least one class per year. Survey results indicate the following:

1. Students thought their understanding of ethics in engineering improved as a result of the ethics modules.
2. Students thought the ethics modules were helpful in preparing them for challenges in their professional career.
3. Students knew the most number of canons from the ASCE Code of Ethics in their fourth year. This is may be due to their exposure to ethics in two classes (Capstone Design and Open Channel Flow) during the fourth year.
4. Student understanding may be improved if they are required to apply more than one canon of the ASCE Code of Ethics.
5. Students appreciated the class discussion, where they learned about more than one ethical situation or approach. Class discussion was also a good opportunity for formative assessment, and students to consider other points of view.

The results of the survey will help improve the ethics modules, and continue our efforts to integrate ethics into the Civil Engineering Program at UP.

References