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Teaching Engineering Students How to Recognize and Analyze Ethical Scenarios

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A two-year study on developing modules for teaching ethics within engineering classes

Abstract

Insufficient formal training in how to identify and navigate ethical situations can leave undergraduate engineering students undervaluing the significance of ethics in their future professional lives. Based on previous literature, we hypothesized that integrating an ethics component into previously established engineering courses will highlight the relevance of ethics in technical studies and provide skills for ethical decision making. However, incorporating ethics into engineering curricula is often hindered a perceived lack of expertise in ethics by engineering faculty. Further, many engineering faculty feel they lack sufficient time to assemble ethics teaching materials. The goal of this work was to develop tools for engineering professors to efficiently and effectively integrate ethics modules into their engineering courses in partnership with experts in teaching ethics. Two student groups developed resources for incorporating ethics teachings into engineering curriculum and evaluated student response throughout various classes.

Phase one of the project aimed to create a guide to allow engineering educators to assemble ethics assignments based on case studies. Two assignments assembled by the student group were given to a class and feedback was obtained. A majority of students reported that they gained an appreciation for the complexity of ethical decision making. Resources for implementing such ethics assignments into an engineering course were compiled in a handbook. Phase two was focused on a joint-venture approach, in which ethics and engineering professors were partnered. The modules were implemented in three engineering courses, with a philosophy professor leading a discussion of ethical theories in the context of a case study in each course. Feedback from the students and professors showed an overall positive response.

In this study, the joint-venture method of teaching ethics in the context of engineering courses was perceived to be effective by students and professors. However, to integrate ethics modules more thoroughly across the engineering curriculum a systematic approach is required with proper accounting of teaching load for ethics/philosophy faculty who lecture in multiple courses. For efficiency, an ethics case-study database with assignment and discussion questions should be maintained, and an online module could be explored with in-class facilitated discussion.

Introduction

With the rapid advancement of technology and integration within all aspects of our society, the ethical implications of our engineering decisions are growing in importance. Engineering professionals have a duty to design and manufacture products that are used to improve the lives of others. In the workplace, dilemmas may arise that can compromise the safety and integrity of a design to accommodate cost reduction or manufacturability. Without understanding the importance of ethics in engineering, engineers may make decisions that will have a negative impact on the very society that they are meant to protect. While many industries do expose their employees to ethics or offer training in ethics, universities can also be a key environment for introducing ethics education.

Studies have shown that many engineering curricula do not sufficiently cover engineering ethics due to lack of systematic exposure[1, 2]. As a result, students may be unaware of the impact of everyday engineering decisions. In 1999, 70% of ABET-accredited institutions did not incorporate an ethics-related requirement for their engineering programs[3]. Of the institutions that did have an ethics requirement, over half the schools did not offer courses that focus on engineering ethics; only courses available from a humanities department were available. Ethics courses taught by humanities faculty may not specifically teach engineering ethics, and students may miss the connection between ethics and engineering.

A comprehensive engineering ethics education covers the basics of research ethics, professional and behavioral ethics, and social ethics[4]. Broadly, there are three main approaches to adding an ethics requirement into a curriculum: a stand-alone traditional ethics course, an across-the-curriculum model, and a joint-venture approach[5]. A growing number of institutions have implemented some form of ethics course to aid students in their gap in ethical knowledge[6]. While other institutions supplement pre-existing engineering courses with ethical material to expose students to ethics[7]. A stand-alone course can provide depth in ethics theory for students, but may not be readily relevant to the students' major branch of study. This detachment may cause lack of interest, and students may underestimate the importance of ethics within their professional lives. Also, trying to fit in another class requirement in an already condensed curriculum may discourage students. Finding the resources needed to create a new stand-alone ethics course for an entire engineering department may also be problematic, as additional teachers may need to be hired to deliver the class[8].

An across-the-curriculum model integrates ethics modules throughout various courses can maintain the relevance of ethics to the engineering subject matter, but at the cost of removing precious time and information from courses to fit in ethics discussions. Removing small amounts of information from the students' classes may have an overall effect on their engineering knowledge. Further, many engineering instructors feel uncomfortable ethics due to lack of education in the competing philosophical theories of ethical decision making. Having an engineering professor teach ethics can be successful only if the instructor is prepared to teach the subject[9]. A joint-venture approach to teaching ethics involves collaboration between engineering faculty and faculty with expertise in ethics, such as philosophy professors, to integrate ethics education in the context of engineering content. Guest lectures break the monotony of an established routine, and may engage and peak student interest[6]. The diversity of multiple faculty perspectives allows student exposure to different fields of expertise, combining both engineering

and ethics material. Implementing ethics into engineering curricula remains restrained by the perception that there is not enough time to adequately address ethics and cover all of the required technical content. Professors may simply touch upon the subject of ethics briefly or avoid the matter entirely[8], and optional ethics classes are often avoided by engineering students due to lack of perceived importance[2]. There remains a critical need for an efficient, systematic means for integrating substantial training in ethical decision making within engineering curricula.

The goal of this work was to develop tools for engineering professors to efficiently and effectively integrate ethics modules into their engineering courses. These tools are designed to be tailored for an across-the curriculum model, in which multiple engineering courses incorporate ethics modules as part of the assessed subject matter. A two-year study was conducted at Worcester Polytechnic Institute with two distinct phases conducted by different undergraduate student teams which developed resources for incorporating ethics teachings into engineering curriculum and evaluated student response throughout various classes. The first phase aimed to develop a set of tools for aiding engineering professors in teaching ethics within their own courses. The second phase expanded upon the results of the first student team by incorporating joint-venture based, customizable modules on ethics to further aid in teaching ethics within an engineering class. Both teams strived to encourage ethical awareness and promote student and professor interest. The ease of use, feasibility, and perceived effectiveness of the ethical tools were determined through feedback surveys completed by professors and students who participated in the study.

Methods

Phase one methodology

In phase one, the first project team sought to develop an easy to use and engaging tool for engineering instructors to implement ethics education within a pre-established engineering course[18]. From research in ethics in engineering education, it was determined that the primary issue to address was that students needed more practice in recognizing ethical problems and knowing how to make decisions. Case studies were chosen as the basis for developing the ethics teaching guide. Engineering classes are filled with technical content and generally do not leave room for other subjects. Therefore, the first team decided the best way to expose students to ethics was to design short and relevant engineering ethics assignments that the students could do outside of class time. After careful literature review, the first team decided to create two types of assignments: a point/counterpoint essay and a heuristics analysis. A senior-level biomechanics class was used for the first study.

A point/counterpoint exercise consists of reading a case study and identifying and analyzing an ethical dilemma within the case study. The participant of the exercise would formulate an argument for one solution to the ethical situation, and then formulate another argument for another, opposite point of view. The goal of the point/counterpoint is to allow participants to reflect upon the multiple facets of ethics and how there is no single “correct” solution. From this exercise, the participants would ideally learn to have an open mind and reflect thoroughly on ethical situations in the future before jumping to conclusions. For the point/counterpoint assignment in this experiment, the first team chose a case study that was related to the topic of the engineering class. The students were asked to write a point/counterpoint essay and discuss

their opinions in class. Upon completion of the point/counterpoint study, the students were asked to complete a survey to gauge how effective this method of ethics teaching was, as well as determine reactions to the assignment.

In addition to the point/counterpoint assignment, the first team also developed a heuristics assignment for the same senior-level class. A six step analysis method was adapted from various sources[10-13]. This analysis assignment would guide the students through various steps in identifying and eventually finding a solution to an ethical scenario. The first step of the analysis involves pinpointing various ethical issues within a given case study as well as the stakeholders. The second step is to present potential solutions for each identified issue. Afterwards, the risks and benefits of the solutions are weighed as well as how the stakeholders are affected by the proposed solutions. The next step is to provide rationale for the solutions and explain how exactly the issue would be resolved. Next, each possible solution is compared to each other to adjudicate the solutions that are most feasible, have the most benefits, and are generally morally acceptable. Finally, the last step is to pick the best solution based on the comparison and rationale.

The goal of the heuristics assignment was to give the participants a systematic way to analyze a case study and find solutions for ethical dilemmas within the case study. The six-step analysis method was explained and demonstrated class. Afterwards, the students were asked to use the six-step analysis method on a new case study and formulate a solution. Upon completion of the heuristics assignment, the students were asked to complete a survey on their opinions of the assignment. Upon compilation of survey data, the first team assembled the "Engineering Ethics Education Handbook" for engineering professors[18]. The handbook discusses the importance of ethics, strategies for relevant case studies, and how to create ethics education assignments.

Phase two methodology

The second project team strived to improve upon the results of the first project team. In order to introduce ethics teachings into engineering curriculum more seamlessly, the second project focused on a joint-venture approach. The second project team developed teaching modules adapted from the results of the first project team. Instead of creating an ethics teaching guide for engineering professors to refer to, the focus of the second project was to create joint-venture modules that can be easily incorporated into pre-existing engineering curricula. The modules consisted of a case study, a point/counterpoint assignment, a guest lecture by an ethics professor, and a heuristics assignment. Each module contained the same underlying format, but differed in the case studies analyzed. The second project team chose the complexity of the case studies according to the class difficulty and picked case studies that were relevant to the class topic to encourage student interest. Modules were implemented into three engineering courses at the freshman, sophomore, and senior level. The goal of the ethics modules was to be easy to incorporate into an already established engineering syllabus, peak student interest in ethics, and provide some baseline exposure to ethics and give instruction as to how to analyze and handle an ethical dilemma. Junior classes were not available for implementing the ethics modules at the time.

In each of the three engineering courses, the students were asked to read their assigned case study and perform a point/counterpoint essay. This assignment was generally interpreted as part of a homework grade, and was expected to aid students in understanding the multiple facets of an ethical problem. Following the point/counterpoint assignment, an ethics professor came in to give a full length lecture on the importance of ethics and how to apply ethical theories to the case study. The ethics professor would also try to highlight aspect of the case study that he or she thought the students might have missed. Following the guest lecture was a heuristics assignment centered on the same case study. The six-step analysis developed from the first project team was adapted for the purpose of this study. Data from the first project showed that their six-step assignment seemed too tedious for the students, so the second project team shortened the assignment considerably while maintaining the key points to the analysis. The heuristics assignment essentially asked the students to identify various ethical aspects in the case study and provide rationale for their opinions on how to handle the ethical scenario. The analysis would then guide the students through how to formulate solutions for the ethical scenarios of their choosing and how to choose an end conclusion. Both the point/counterpoint and heuristics assignments were meant as tools for the students to practice and use in preparation for any ethical situations that may arise in their future professional careers. Completing the entire module was worth a small portion of the students' final grades, determined by the engineering professor.

Following the heuristics assignment was a student survey used to evaluate student opinion on the ethics module and whether they found the module useful. The engineering professors and ethics professors involved in implementing the modules were also asked to provide feedback on the usage of the module.

Results and Discussion

Phase one: in-class modules

Throughout this two year study, case studies were used as the basis for assignments and ethical thinking. Using case studies requires for the students to understand the situation and explore the various aspects to an ethical issue, allowing for an engaging experience[14]. For the first phase of the project, ethics education assignments were integrated into a senior-level biomechanics class. The class had a total of 79 students. The point/counterpoint assignment had a 94% participation rate, as the homework was worth 2% of the students' final grades. Results from the assignment showed that the class was fairly polarized in opinions for the first part, where the students voiced their own beliefs. After completing the assignment, 20% of participating students changed their original viewpoints on the case study, seen in Figure 1. This change in mindset indicates that the students considered other options than their personal belief, and found that they were able to rethink about the problem and result in a more informed decision. For students that did not change their mindset, their original beliefs could be more firmly supported. Only 44% of students filled out the after-assignment survey for the point/counterpoint homework; the survey was not worth any credit towards the final grade, demonstrated in Table 1. The responses from the students were general one paragraph for each point of view. According to the feedback given by those who filled out the survey, the students generally stated that they learned much from the debate. Many students felt they learned how

complex ethical decision making can be, and playing the "devil's advocate" broadened their mindset.

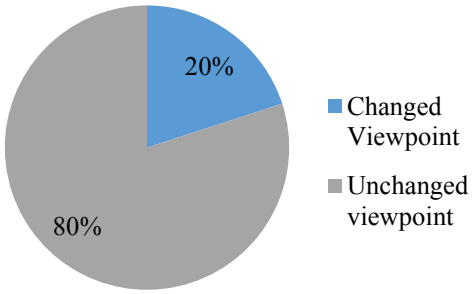

Figure 1: A substantial number of students changed their viewpoints after a point/counterpoint assignment.

There was a 92% participation rate for the heuristics study, which was also worth 2% of the final course grade. The heuristics survey was included in this assignment. Overall, the heuristic assignment was more in-depth than the point/counterpoint assignment, so the students wrote much more. From survey responses, many students enjoyed the concept of the six-step analysis, which allowed them to organize ideas more easily and keep track of all the ethical issues within the given case study. Students indicated that this method made complex ethical dilemmas easier to understand and analyze. Of the students that answered the survey, 79% indicated they would keep a copy of the six-step analysis for use in the future. Some students stated that they felt the case study did not provide enough background for them to make a satisfactory decision, and as a result chose solutions based on personal moral values. In addition, some students claimed the heuristics assignment was time consuming and repetitive. When asked whether they preferred the point/counterpoint or heuristics method of ethical analysis, the students generally could not choose. They recognized that the point/counterpoint method was useful for more simple case studies, while the six-step analysis would be a better fit for complex cases.

After both assignments were completed, the course instructor was asked to provide feedback on implementing the case study assignments. The instructor agreed that the assignments were useful in exposing students to ethics. The discussions for both methods were approximately 30 minutes each, and prior preparation took two hours. The professor indicated that the point/counterpoint method seemed easier for the students and was less work than the 20% 80% Changed Viewpoint Unchanged viewpoint heuristics assignment. Observationally, it was noted that the participation rates were much higher if the assignment was worth a small amount of the course grade, as seen in Table 1.

Table 1: Response rate and grade distribution for Phase One

Assignment	Response Rate	Final Grade Weight
Point/Counterpoint	94%	2%
Point/Counterpoint survey	44%	0%
Heuristics	92%	1%
Heuristics survey	92%	1%

Overall, participants indicated a positive attitude towards the ethics assignments. The data collected showed students were exposed to more ethics in the classroom, and many recognized the importance of ethics. With the resources collected from assembling the case assignments, the first team assembled a handbook to ease the incorporation of ethics into engineering courses[18]. The handbook is meant as a guide to aid engineering professors in easily adding ethics assignments to their syllabi.

Phase two: joint-venture approach

For the second phase of the project (year two), ethics modules were integrated into three engineering courses in collaboration with three philosophy instructors. The team decided to focus on the joint-venture approach over other methods based on the phase one data and a preliminary study incorporated into a sophomore level biomechanics class which exposed students to three different methods of teaching ethics: a lecture from the engineering professor, a point-counterpoint assignment, and a guest lecture. From Figure 2, it can be seen that a majority of the students, 57%, preferred the ethic professor's lecture and discussion.

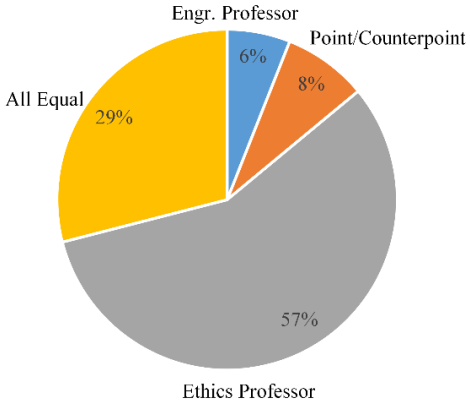

Figure 2: Student preference of the three ways of teaching ethics from the pilot study. The majority of the students indicated a preference for the joint-venture method in a post-course evaluation, with n=60 of 85 students in a sophomore-level biomechanics class.

When interviewed, the engineering professor also indicated that he favored the guest lecture, as he felt that the ethics professor was able to discuss the ethical theories and implications in greater detail due to his formal training in ethics. In addition, 80% of the students claimed to have learned something new from the guest lecture, and would like to see a similar ethics approach in the future. In all three engineering classes used for the phase-two study, the majority of students participated. Table 2 shows the details of student participation in each course.

Table 2: Response rate and grade distribution for Phase Two

Course Level	Number of Students	Response Rate	Final Grade Weight
Freshman	81	90%	Bonus
Sophomore	94	76%	3%
Senior	28	93%	5%

It was speculated that the lower participation rate in the sophomore level class was due to the intense workload of the students, as the students had multiple other assignments, exams, and

projects to complete within a short timeframe. Perhaps a higher grade incentive would have increased the participation rate, which was fairly high nonetheless.

Previous studies have suggested that a key part to learning ethics is contemplating and understanding the components of an issue and the various directions a solution may take[15]. For phase two of the project, both a point/counterpoint and a heuristics assignment were given to the students. The reason for the multiple assignments is to ensure that students thoroughly go through an ethical scenario. The in-depth assignments and guest lecture were designed to have a lasting impression on the importance of ethics.

Results from the student feedback surveys showed an overall positive response to the ethics modules, as shown in Table 3. Over 80% of all participating students indicated that they learned something new regarding how to analyze ethical situations, and felt more confident in tackling an ethical situation after completing the module. Over 90% of the participating students found the guest lecture helpful in understanding ethics, while only a minority of the students felt the ethics module may have distracted them too much from the core technical content of the class. Importantly, over 90% of participating students also felt they could know how to identify, analyze, and handle and ethical situation in the work force. These data show that the joint-venture module was both successful and popular in exposing students to ethical content and tools. The perceived confidence showed that students felt more comfortable towards ethics and have an improved ability to handle ethical situations. Student interest in ethics was also peaked, as 70% of participating students showed that they would consider a more in-depth ethics course in the future. Feedback from ethics professors also showed that many students approached them and expressed an interest in the topic after the ethics guest lecture had concluded.

Table 3: Average student responses of all three courses to effectiveness of expanded study

Question #	Question	Yes
1	Did you find the ethics guest lecture helpful in understanding the assigned case study?	90.5%
2	Did you learn anything new regarding how to analyze ethical situations?	82.4%
3	If encountered with an ethical situation in the work force, would you know how to identify, analyze, and handle it?	90.6%
4	Are you any more confident in facing an ethical situation now than you were in the beginning of the term?	81.7%
5	Did the ethics module distract from the technical core course work too much?	10.6%
6	Would you consider taking a full (1/3 credit) BME ethics course?	70.6%
7	Would you want BME courses to incorporate a similar ethics module in the future?	84.6%

An interesting pattern in the student opinions, shown in Figure 3, is that the students felt that they learned more from the ethics module in upper-division courses than in lower-division courses

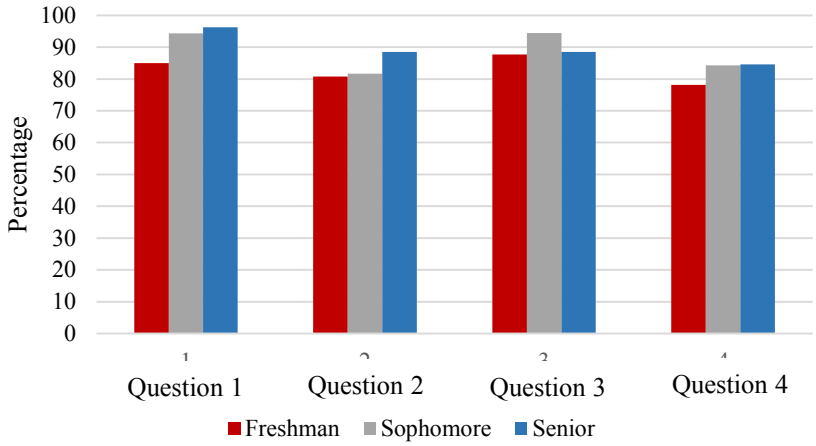

Figure 3: Visual comparison of class levels with positive student response. The questions shown correspond to the questions asked in a student survey regarding the effectiveness of the module, as shown in Table 3. The overall average positive response percentages for each question are displayed.

Upon the completion of the ethics modules, the second project team interviewed the engineering professors and ethics professors to gather input on using the module. The engineering professors felt that the modules were easy to incorporate into their class schedule, and that the ethics content was not too distracting from the main engineering material. The assignments were also formatted in such a way that they could conveniently be added to homeworks. The engineering professors all indicated that they would definitely use the ethics modules in future courses. One professor did indicate that he felt the ethics guest lecture may have been too complex and confusing for the students, which caused some confusion. Nonetheless, all the engineering faculty agreed that the joint-venture approach was successful in that the students were exposed to ethics by ethics professionals. Engineering faculty may not have the expertise to sufficiently teach their students about ethics. Having an ethics expert come in and discuss the subject allows for both students to learn from an expert and for the engineering professor to gain a better understanding of how to incorporate ethics into their curriculum[16]. There is also a perceived expertise with an ethics professor teaching ethics materials, and students may feel that the material is more reliable and credible[17]. From the post-module surveys, the engineering professors seemed to be more accepting of an ethics module, especially since they are not required to lecture on the material. The engineering faculty have great confidence in the ethics professionals to expose students to ethics, and their willingness to help shows students that ethics is important and relevant.

The ethics professors who participated in the modules indicated that the guest lectures were easy to prepare, since the material is pre-established in their old lectures for other classes. The ethics professors also thought the ethics module was a significant contribution to exposing students in engineering to ethics, but lacked an in-depth component to fully immerse students in ethical theory. Time was a major constraint in the ethics module, since a course has a limited number of hours to teach technical content. Including an ethics component such as the developed module took some time from the technical side of the course, but exposed students to important ethical tools and raised awareness.

Broader implementation

In this two-year project, the teams developed tools for engineering faculty to aid in meeting students' needs for ethical training. While progress has been made, much work still needs to be done towards developing a more comprehensive and formal system. Ethics professors who volunteered in this study recommended for future module iterations to have a more in-depth component to ethical theory. The handbook and joint-venture modules suffice to introduce students to the topic of engineering ethics within individual engineering classes, and give students a few tools to help identify and resolve ethical issues in their future. However, each module developed was intended for use in a specific class and do not adequately address the issue of incorporating an ethics component to a student's overall education within an engineering curriculum. For a comprehensive across-the-curriculum ethics component, work needs to be done to relate ethics in every class a student takes without becoming repetitious and disinteresting for the students. The complexity and depth of ethical studies should also be increased as classes become more difficult. By the time a student graduates, the student should have a complementary ethics education with their engineering education.

For a joint-venture approach, issues may arise in time conflicts and scheduling for guest lecturers from ethics professionals. Ethics faculty still need to be reimbursed for their work and time, and cannot feasibly volunteer continuously as they have their own responsibilities and classes to attend to. More efficient methods should be looked into for incorporating a joint-venture ethics module. It is recommended that future studies explore an online ethics module to accompany existing engineering courses. The online ethics content could be created by ethics professors to ensure a more complete ethics education. The online module would also save time and resources for all parties involved. Reading material and assignments can be distributed electronically, and engineering and ethics faculty can work together to develop a system of evaluating student ethical development. However, an online module would require considerable coordination and work from both engineering and ethics teaching faculty. Online lectures also lack a more personal component in teaching, and students would not be able to have live discussions or ask questions immediately. Despite these drawbacks, online content modules would still be beneficial in that they can cover significant content and provide immediate tools for ethical analysis.

Conclusion

The difficulty in effectively teaching ethics across engineering curricula may leave students unaware of the importance of ethics in everyday decision making in their professions. In this work, the use of tools for incorporating ethics teachings into engineering classes efficiently and effectively was explored. A handbook was developed to aid engineering professors in selecting case studies and formulating assignments. A joint-venture approach involving collaboration with ethics professors for more effective incorporation into the engineering curriculum was also developed. Overall, the systems developed were shown to be successful in exposing students to ethics and improving their knowledge on ethical decision making. To integrate ethics modules more thoroughly across the engineering curriculum a systematic approach is required with proper accounting of teaching load for ethics/philosophy faculty who lecture in multiple courses. For efficiency, an ethics case-study database with assignment/discussion questions should be maintained, and an online module could be explored with in-class facilitated discussion.

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