Students Taking Action on Engineering Ethics

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Creating an Engineering Action Plan for Ethics

Abstract

The purpose of this research was to develop a classroom project module that supported students in developing an action plan for ethics. The module connects ABET criteria related to ethics and evolving research in ethics in other disciplines. The module was implemented in the context of a larger project in a junior level heat transfer course. A student survey was developed and measured student perceptions of learning objectives. Students reported they found the activities helpful for building the skill of ethics action planning, particularly the ability to explore multiple solution paths. The results indicate this type of action planning module may play an important role in character development for engineers that goes beyond case studies.

Introduction

This paper describes a classroom module designed to increase engineering student skills in ethics. Traditional engineering ethics education has focused on case studies of past engineering disasters [1].

In the business discipline an alternative viewpoint on ethics education has been articulated by Mary Gentile [2]. She argues that students often have a strong ability to identify an ethical challenge, but they may not have the skills needed to articulate it in a professional context. For engineering students, this implies that they can easily identify that they should not replicate past disasters by designing a bad bridge or flawed device. However, the professional culture may create competing forces like cost and career progress. Gentile articulates that students must be trained in how to communicate ethical concerns to superiors, and the skill must then be practiced. This module was designed to do both of these things for engineering students.

The module developed had several learning objectives:

1. Develop an action plan to modify or address an ethics or character issue
2. Explore multiple solution paths
3. Identify the needs and motivations of various stakeholders

The research goal of the project was to determine if a structured module in an engineering course could help students enhance the skill of building an action plan for ethics. The skill is important for engineering students, and ties directly to ABET student outcome 3, “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.” [3].

This module is also part of a larger effort at the University of Portland to embed the entrepreneurial mindset across the curriculum. One facet of the entrepreneurial mindset as defined by the Kern Entrepreneurial Engineering Network (KEEN) is supporting students in developing advanced skills and mindsets to equip students to create personal, economic, and

societal value [4]. Improving student skills to speak out about character issues is an important part of creating both economic and societal value.

Background

Many prior authors have published in the field of engineering ethics. Most of those papers focused on a traditional approach to teaching students ethics, focused on engineering disasters and case studies. Stephan summarized the ethics courses required at engineering courses in institutes around the country [5]. Haws provided an overview of 42 different ethics papers published in the American Society of Engineering Education [6]. Hess and Fore [1] analyzed 26 articles, and found that the most common methods of teaching ethics included "exposing students to codes/standards, utilizing case studies, and discussion activities". Hess and Fore also highlighted the measurements of how students learn across these articles. A summary of prior work on engineering ethics in the classroom is shown in Table 1.

***Table 1**. Summary of engineering ethics methods from the literature.*

Author	Year	Pedagogical Elements	Ethics Focus Area
Carpenter et al. [7]	2005	Challenge game	Professional and ethical responsibility
Wittig [8]	2013	Problem Based-Learning	Ethical decision-making
Troesch [9]	2016	Phenomenological approach	Ethical reasoning and emotional engagement with ethics
VanDeGrift et al. [10]	2016	Survey	Academic Integrity
Doughty et al. [11]	2017	Lab module and project	Aspirational ethics
This Study	2019	Active learning, project, action plan	Professional action plan and entrepreneurial mindset

None of the prior works in engineering ethics have focused on the development of action plans as a skill for students.

Ethics Module Design

The module was designed to be added to an existing class project so students had context for building an action plan for ethics. The module was implemented in a heat transfer course, but was also implemented in a slightly different context/project in a fluids course. With small modifications it could be added to other classes. This module was implemented in a junior level required class on heat transfer with mechanical engineer students. The project was groups of 2-3 students, with around 40 students in the class.

The students worked the first half of the project to design a device to transport a vaccine and keep it cold for 48 hours. The first half of the project had all the normal elements of project-based learning for a heat transfer course. The students first used a 1-D resistor model for the device they designed. The constraints for the design were focused on cost and weight. Students

quickly became attached to the design and performance of the device they had spent several weeks thinking about. Leading up to the ethics dilemma, the students watched a video about the importance of vaccines for specific individuals in the countries they were designing for.

Ethics Dilemma - During the ethics module, students were then told that the company they worked for changed the plan, and the device would now be used to transport the vaccines for 5 days longer (7 days total) without the ability to refrigerate the vaccines in the interim. For most of the students, this new constraint meant a complete re-design of the device they had planned would be required or they would need to approach a manager to address this new constraint.

This dilemma was the focus of how the students proceeded to make an action plan. The in class activity started with a four-squares voting activity with several options for students to think about. An in-class worksheet was used to guide them to analyze the needs of all the stakeholders (the vaccine users, the manager, their own careers), and then determine how they would communicate the plan they developed to a manager. As part of the action plan they were asked to estimate the cost and human impacts of the alternatives they brainstormed. An example of the table students were asked to complete is shown in Table 2. All of this was designed to develop skills and habits to help them make an action plan for an ethical concern in the future.

Table 2. *Example of one portion of the in-class exercise to help students frame an action plan for ethics.*

Now consider the best formal response your team could make to your boss. Think carefully about what will motivate your boss to respond in the way you wish.

Analysis Parameter	Scenario 1 – Take the extended vaccine trip as planned	Scenario 2 – [Alternative determined by your team]	Scenario 3 - [Alternative determined by your team]
Cost of Transportation			
Number of lives impacted			
Projected cost of health effects and legal costs			
[Other impacts as determined by your team]			
[Other impacts as determined by your team]			

The students had to include the completed ethics plan in the final design report along with the more technical specifications for the project. Students had around four weeks to complete this part of the project. Students needed knowledge of cost estimation and could then research the alternative ethics scenarios they proposed. Lecture materials and homework prior to the project included heat transfer material, specifically the thermal resistor analogy, transient analysis, and multi-mode analysis.

Assessment Methods

The overall results of this research involved two parts, an external observation and a student survey. The survey asked students to self-assess the specific learning outcomes on a Likert scale and write an open-ended response about the learning objective. An example of the format for this survey question is shown in Table 3. After the students completed the survey, the essay results were analyzed using a natural language processor in the R statistical program [12].

Table 3. *Example of student survey questions where students were asked to consider each learning objective on a Likert scale.*

For the learning objective listed below, please rank the extent to which your capacity increased **during this class**. (circle one) Then, please elaborate with a specific example.

Question	Not at all	Very Little	To a Small Extent	To a Moderate Extent	To a Great Extent
To what extent has your ability to develop an action plan to modify or address an ethics or character issue increased?	1	2	3	4	5
Describe a specific example of how your ability to develop an action plan to modify or address an ethics or character issue increased in this class.					

Ethics Module Results

The results for the module were very good for a first time offering. All the student groups included the completed table (Table 2) for alternative ethics plans in the final project report. Several groups did an excellent job researching the costs of transportation and showing that several smaller trips would be cost effective when the possible legal issues were considered. Some of the groups also wrote strong justifications about the value of human lives and the moral concerns about delivering compromised vaccines. This outcome was the goal of the activity and assignment.

Student Survey Assessment

The student survey was completed by 35 students, representing about 88% of the possible respondents. All the respondents were mechanical engineers and six were double majors. The

summary of the results is shown in Table 4 and Figures 1-4. Student responses indicated that the objective "explore multiple solution paths" was statistically significant when compared the other learning objectives.

Table 4. *Summary of student survey question results.*

Objective	*n*	*Mean*	*Standard Deviation*
Identify the needs and motivations of various stakeholders	35	3.47	0.85
Explore multiple solution paths	33	4.03	0.77
Develop an action plan to modify or address an ethics or character issue	35	3.57	0.82

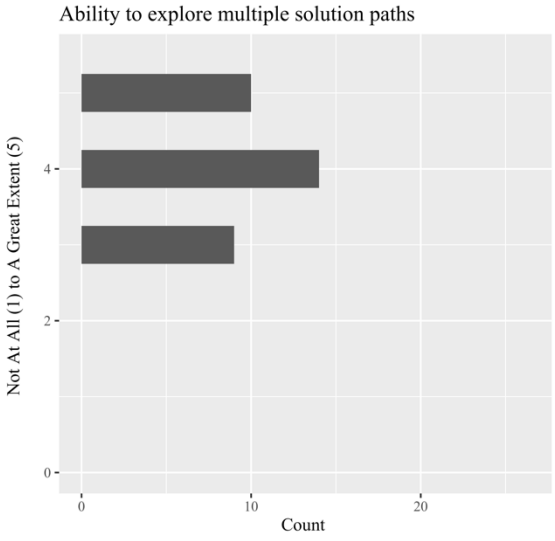

Figure 1. Student responses to the learning objective "Ability to explore multiple solution paths".

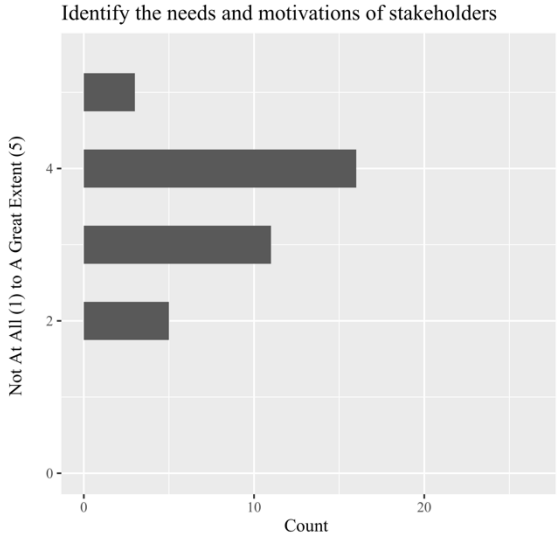

Figure 2. Student responses to the learning objective "Identify the needs and motivations of various stakeholders".

For each learning objective, students were also asked to describe a specific example. The student essays were summarized using a natural language processor and a word cloud of the responses is shown in Figure 4. Students highlighted terms like "project" and "ethics", words that were well aligned with the goals of the module.

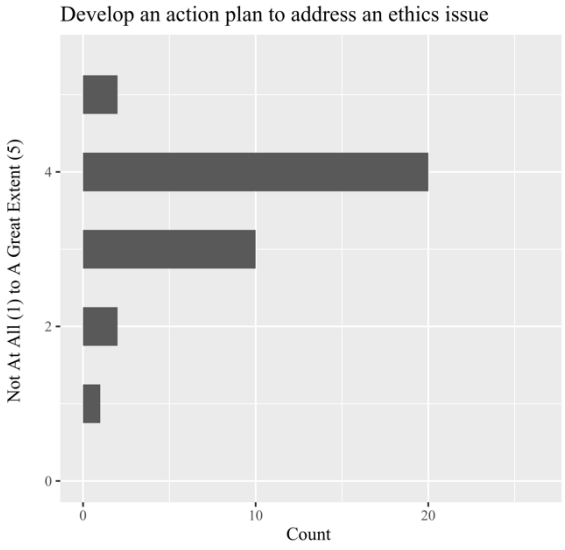

Figure 3. Student responses to the learning objective "Develop an action plan to modify or address an ethics or character issue".

Figure 4. Student natural language summary of the open-ended essay questions.

Student responses to each of the learning objectives were categorized by themes. For the learning objective, "Identify the needs and motivations of various stakeholders" several themes occurred.

- Students reported the ethics project helped them consider various perspectives of the stakeholders when designing a solution (38%; *n* = 13 students).
    - "I wouldn't have thought about the different viewpoints of stakeholders otherwise."
    - "Before this exercise, we hadn't really considered real impacts that heat transfer calculations can actually have."
- Students commented that the ethics project compelled them to prioritize the needs of stakeholders (29%; *n* = 10 students).
    - "There's so many aspects to consider. This project helped to narrow down the important ones."
- Students commented the ethics project helped them practice making decisions (29%; *n* = 10 students).
    - "With this class there are a lot of options one can use to solve for a problem."

For the objective, "Explore multiple solution paths," students themes included perseverance.

- Students reported that the ethics project challenged them to persevere to find solutions (39%; *n* = 13 students).

    - "A lot of the stuff we tried didn't work at first which forced us to try different approaches. Sometimes that meant starting over or just iterating for better results"
- Students commented the ethics project helped them use a variety of (multiple) solutions to solve a problem (64%; *n* = 21 students).
    - "This project made you come up with more than one idea as well as the pros/cos for this idea. This made it so you didn't stick with just one idea and expanded your field of thought."
- Students commented that the ethics project helped them collaborate in a team to solve a problem (12%; *n* = 4 students).
    - "Two brains are better than one, talking with the group and thinking over different solutions helped.

For the last objective, "Develop an action plan to modify or address an ethics or character issue," student trends were more complex. Some of the student comments highlighted the value of the ethical dilemma for this aspect of reaching the project goals.

- Students commented that the ethics project helped them consider the impact of their own decisions as an engineer (26%; *n* = 9)
    - "Working through a project that could benefit communities allowed me to really think about how my team's decision could positively or negatively impact people in need. 'What are my obligations as an engineer' came up during the team's ethical decisions.
    - "The tables on the in-class exercise got me to think in different perspectives because it talked about the different parties motivations. I also thought about how it would affect the other people instead of just me."
- Students commented that the ethics project helped them consider multiple perspectives (40%; *n* = 14 students)
    - "The first in-class exercise about the ethics showed me that I should look at an ethics problem from the point-of-view of ALL parties."
- Students commented that the ethics project helped them create action plans and/or modifications to a plan when confronted with ethical considerations (29%; *n* = 10 students).
    - "Really good to put emphasis on ethical engineering. When lives are at risk we had to develop a real action plan to prevent harm from happening."
    - "developing plans of action were fairly simple, but the ethics is what made it complicated.
- Students commented that the ethics project helped them to evaluate solutions (34%; *n* = 12 students).
    - "The team needed to evaluate what to do when people's lives are being affected"

- "In viewing the situation, this project allowed me to analyze the ethics of a real-world situation. Having a conflicting option (with my boss ethically) was something I hadn't thought about. This project was beneficial."

Conclusions

A new project was developed for engineering students to help them develop specific skills for navigating professional ethics challenges. The module was incorporated into an existing design project about vaccine transportation. The ethics dilemma was designed to create conflict between the engineering design team and management, mimicking the complex situations that students may someday encounter in industry. The project structured the process of creating an action plan for approaching this issue with management.

Students in a junior level heat transfer course tested this module in the spring of 2019 and the educational methodology was a success. Students reported that the module had been successful for most of the learning objectives, particularly for increasing their ability to explore multiple solution paths. The results indicate this type of action planning module may play an important role in character development for engineers that goes beyond case studies.

Future work will include adjusting this type of action planning module in other classes in the curriculum. We believe this type of scaffolding for action planning on ethics is critical to building the mindset of future engineers.

Acknowledgements

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