Effectiveness of Ethical Interventions in a First-Year Engineering Course: A Pilot Study

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Why engineering ethics?

Engineering ethics is defined as the standards of behavior and moral principles that govern how an engineer should act in the diverse situations in which they find themselves *in the engineering profession.* Since the addition of "an understanding of professional and ethical responsibility" as a requirement for ABET accreditation [1], there has been renewed interest in the scope and practice of ethics education in engineering curricula. While ethics education is now mandated for accreditation, the form that education takes varies considerably with each program.

Despite the increased awareness and codification of ethics into engineering education over the last two decades, there is continual debate about the efficacy of ethics education and the ability of educators to make a positive impact on students' moral development [2]. At least one prominent study [3] has documented skepticism amongst faculty with respect to the (positive) nature and influence of the ethics education provided. In a broad survey [3], these authors noted (1) the non-uniformity with which ethics education was organized at the course and program levels and (2) the commonly held viewpoint among engineering educators that ethics is entirely subjective and personal, and therefore difficult or impossible to assess. While source (1) is a systemic issue that may be corrected through programmatic change, source (2) is more personal and ultimately may *influence* the former.

This misconception (2) stems in part from the fact that modes of learning and evaluation present in the context of engineering ethics tend to take a qualitative approach that is often unfamiliar practice for engineering educators. For example, active learning strategies such as reflective moral experiments [4] and ethics analysis exercises [5] have become increasingly common for assessing student decision-making processes. Likewise, it is difficult to assess the depth with which students consider their ethical decision-making (i.e., do students respond with the answer they *think* their instructor wants, or with the answer they truly believe to be the most ethical? Do they consider the breadth of possible solutions and weigh the pros and cons of each?) Unfortunately, the majority of engineering programs do not assess the ethical reasoning or moral development of their students before being exposed to engineering ethics education, making it difficult to accurately measure student thought processes and development over time. This lack of pre-assessment makes it difficult to determine the effectiveness of instructional interventions aimed at augmenting ethical decision-making skills.

Purpose

The purpose of this study is to characterize the moral development of first-year engineering students in a freshman engineering course and examine how ethical and moral outlooks change throughout the first-year curriculum when exposed to ethics interventions. The research questions investigated are

1. What is the ethical and moral "baseline" of first-year engineering students before exposure to ethics education?
2. What are the effects of a specific set of ethics interventions on the student's ethical decision-making skills?

It was hypothesized that, despite the diverse moral and ethical experiences of the students, the interventions will lead to increased levels of moral sensitivity and increased ability to make informed ethical decisions. Characterization of ethical reasoning and moral development were accomplished using a pair of related instruments designed for this purpose, in conjunction with a survey of student attitudes and opinions about the effectiveness of different interventions. It is anticipated that the data and feedback collected will help guide future pedagogical decisions and help refine the ethics education embedded within the course. Furthermore, it will serve as a pilot study for a future longitudinal study of ethical decision-making among engineering majors across their undergraduate educational trajectories. It is hoped that this research will be of interest to engineering programs wishing to enhance the way they evaluate their ethics education curricula, whether in stand-alone courses or in ethics-centric course modules.

Ethics-based interventions

The instructional interventions consist of classroom and homework activities focused on providing students with practical ethical decision-making strategies. All interventions are modular in nature, and exist as sub-units within the context of a general first-year engineering "clinic" course at Rowan University. These interventions include several active and game-based learning activities such as an engineering ethics card game [6], an ethics case study analysis assignment, and personalized assignments on engineering ethics using a gamification platform called GameLab [7].

Classroom activities

The ethics card game [6] was introduced after an introductory lecture on ethics and the process of ethical decision-making including sample case study analyses. This engineering ethics card game is based upon the recently published ASEE Work-In-Progress by Burkey and Young [6]. The game consists of a "Cards Against Humanity" style challenge and response, in which one player acts as the dealer and the remainder of the players act as respondents. The dealer chooses a *Black Card* containing an engineering scenario, to which the other players must submit *White* response cards. The dealer then chooses the "best" response, and a point is awarded to the owner of the chosen card. The role of dealer then rotates and the process repeats. While the *Black Cards* all contain real engineering ethics scenarios, the *White Cards* range in both their applicability and their seriousness (see Table 1):

Table 1. Sample Black Card and White Cards

Black Card	White Card 1	White Card 2	White Card 3
The Molasses Flood of 1919 could have been avoided if ___ was used to plug the hole	A faked safety report	Duct tape and prayer	An angry mob made entirely of penguins

After playing the game, the instructors led the students through a debriefing session aimed at teasing out the ethical issues of the black cards and appropriateness of the white response cards, with the goal of getting the students to reflect upon their choices. The students were also

encouraged to submit new card suggestions to the instructor, which were curated and forwarded to the game's creators.

Out of class activities

In addition to the classroom activities described above, the students were given several out of class assignments to complete. The first assignment was to choose their own engineering ethics case study to research and analyze. In this individualized assignment, the students were tasked with providing a summary of the case and identifying the ethical dilemmas faced by the engineer, putting themselves in the position of power to make the final choice of action. They were to provide several alternative solutions to the dilemma and justify their final choice using the professional codes of engineering ethics applicable to their case.

The second set of out of class assignments involved a gamification platform called GameLab [7]. Gamification refers to the application of game-based elements to a non-game based activity, often using points and rewards. In GameLab, students are able to complete individualized activities or "quests" based on their interest level. These activities are scaffolded for students to ensure that they meet a minimum set of learning objectives across the course. The quests cover a variety of first-year engineering topics, from product development to teamwork. One of the categories in GameLab is ethics (an example quest is shown in Figure 1). Students are assessed on these quests as either "approved" or "returned", meaning that students either get full credit and pass the quest, or fail the quest and have to resubmit. This allows instructors to give timely, meaningful, and personalized feedback and for the student to learn from their mistakes and engage in more practice. Because of the customizable nature of the platform, students did not complete all eight possible ethics quests, but were at least required to complete two as part of an introduction badge. Most students completed 3-4 ethics quests by the end of the semester. This platform was useful from a data collection standpoint as it gathers student submissions over the course of the entire semester

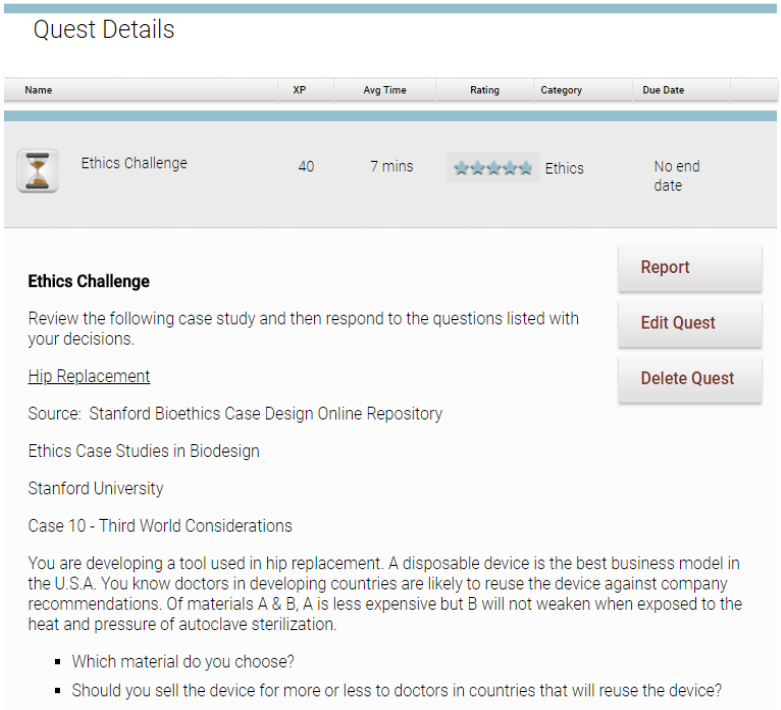

Figure 1. Example of an ethics quest in GameLab Gamification Platform

Methods

Students from Rowan's Freshman Engineering Clinic course were invited to participate in this pilot study to evaluate the ethical decision making of first-year engineering students. The study consisted of two related tests that assess the moral judgement of individuals when faced with ethical dilemmas and a focus group to provide insight upon the students' perceptions of the above-mentioned interventions' effectiveness as well as the efficacy of the tests. Recruitment for each test and for the focus group were conducted independently, but the students were always recruited from the same two sections of the course (n-range 28-34). This study was approved by the institutional review board at the University (IRB# PRO2017002152) and may form the basis of a long-term project in the future.

The tests consisted of two related instruments – the Defining Issues Test version 2 (DIT-2) [8] and the Engineering Ethical Reasoning Instrument (EERI) [9]. The DIT-2 is used to assess the moral judgement of individuals when faced with ethical dilemmas. In this test, a specific set of five (5) ethical dilemmas is presented to the individual, who must decide how to solve each dilemma. The individual is then presented with a series of statements suggesting *how they made their decision* which they must rate in importance terms from "Great" to "No Importance". Finally, they rank their top 5 statements in order of most to least important. An example DIT-2 question prompt is given below [8]:

"The small village in northern India has experienced shortages of food before, but this year's famine is worse than ever. Some families are even trying to feed themselves by making soup from tree bark. Mustaq Singh's family is near starvation. He has heard that a rich man in his village has supplies of food stored away and is hoarding food while its price goes higher so that he can sell the food later at a huge profit. Mustaq is desperate and thinks about stealing some food from the rich man's warehouse. The small amount of food that he needs for his family probably wouldn't even be missed.

What should Mustaq Singh do? Do you favor the action of taking food?"

Each of the student-ranked statements is designed to correspond to one of Kohlberg's stages of moral development [2]. In Kohlberg's model, moral decision-making is broken down into separate stages ranging from stage 1 to stage 6 that delineate *how* a person arrives at an answer to a moral dilemma. Stages 2 and 3 are termed *preconventional* thinking, and correspond to thought processes that are self-centered. For instance - the rationalizations such as "I want X so I will do Y" and "I will do X because if I don't, I will be chastised" are examples of preconventional thinking. Stage 4 is termed conventional thinking. Stage 4 thought processes center around the moral frameworks that social groups impose on individuals, and can be expressed in phrases such as "X is the law, so I will do X" or "I will not do Y, because Y is against the rules." Stages 5 and 6 are termed *post-conventional.* Post-conventional thought concerns the evaluation of situations individually, based on one's self-imposed sense of moral right and wrong, regardless (or in spite of) the moral framework in which the individual is immersed. While originally conceived as distinct phases in moral development [2], it is now accepted that most individuals exhibit all of these different "stages" in varying amounts at any given time, which may differ depending on the exact moral situation one is exposed to. Therefore, when scoring the DIT-2 an individual receives a score 'profile' consisting of the personal interest score (stage 2/3), the maintain norms score (stage 4) and the post-conventional or "P" score (stage 5/6). These scores are calculated based upon the quantity of particular stage statements that a student chooses to include in their top-five list and the order in which they were ranked. In addition to the stage scores, the test has an

additional score to encapsulate the extent to which a subject rejects lower stage statements (Stages 2-4) and favors higher stages (Stages 5-6), called the N2 [10]. The N2 score was introduced because in the previous editions of the test, respondents were scored only upon their ability to rank their responses - no weight was given to the *rating data* about each statement. The N2 implicitly contains information about the ranking of Stage 5-6 statements (P score) and rating of *all* statements, and has been shown to out-perform the "P" score [10]. For a detailed explanation of the P and N2 scores and their calculation, readers are encouraged to see [10]

The DIT-2 has been extensively validated and benchmarked for different age groups and levels of education [11]; for university undergraduates, the average scores and standard deviations for each category (n > 32000) are provided below in Table 2.

Table 2. DIT-2 norm scores [11] for undergraduate students (n = 32,974).

Score	Average	Standard Deviation
Personal Interest (Stage 2/3)	25.04	12.36
Maintain Norms (Stage 4)	35.06	13.89
Post Conventional (Stage 5/6)	35.09	15.21
N2	34.76	15.45

One limitation of the DIT-2 is in the lack of engineering scope within the scenarios presented. The scenarios are not always relevant to the engineering profession and lack direct application to the team-based skills that are crucial elements of engineering decisions. The Engineering Ethical Reasoning Instrument (EERI) [9] is a tool designed specifically to assess ethical reasoning and decision making in *engineering scenarios* and is based off the DIT-2 instrument. An example EERI question follows:

"Your student design team has designed a new Soap Box Derby car that allows children with physical and cognitive disabilities to race by allowing an adult to ride in a backseat and maintain full control of the car. Based on suggestions from the adults, you have added spring tension to the child's steering wheel in front in order to simulate the feeling of driving and make the child's experience more realistic and fun. The child will not have the ability to control the car, only the illusion of control. Before the first test run with an adult and a 14-year-old child onboard you hear the child's parent tell the child to "be careful" and to "drive safely." The parent turns to you, explains that because of a cognitive disability the child likely won't understand the difference anyway, and asks you to tell the child that the front steering wheel is actually functional. The request that you lie to the child would take advantage of the child's disability and it creates the possibility that the child would feel responsible if they were to lose the race or have an accident.

Would you lie to the child?"

The EERI is still in the process of validation and benchmarking due to the short period of time since its initial publication (2014) [11]. As such, the DIT-2 and EERI were used in tandem to offer complementary insight on student moral development from both a general and an engineering perspective. These instruments were implemented using a pre-post testing model with the EERI

administered at the beginning and end of the semester and the DIT-2 administered at the end of the semester for comparison purposes and to provide additional stage-specific information.

Results and Discussion

Quantitative Results

DIT-2

The average P and N2 scores for the DIT-2 posttest (n=30) are presented below in Table 3. Both the P and N2 scores are in the high 30s, which is higher than average for university undergraduates, yet well-within one standard deviation of the DIT-2 norms (Table 2). Likewise, this population's average Personal Interest score is very close to the undergraduate norm, while the Maintain Norms score is only marginally lower than average. Taken together with the P and N2-scores, this indicates that the average moral profile of this cohort when concerned with general social phenomena is typical for undergraduate students (freshmen through seniors). There are very few similar studies that have been conducted with freshmen using the DIT. Two in particular are of note for their similarity to the current study. The first was composed of computer science [13] majors and the second of business [14] majors, which both indicated P scores in the mid-20s. As such, this group of freshman engineers may be considered above average when compared to other first-year students in technical majors and professional programs.

Table 3. Comparison of averages for the DIT-2 norm scores [11] with DIT-2 post-test scores

Score	DIT-2 Norms	DIT-2 Posttest	Difference (Δ)
Personal Interest (Stage 2/3)	25.04	23.93	1.11
Maintain Norms (Stage 4)	35.06	31.20	3.86
Post Conventional (Stage 5/6)	35.09	39.20	-4.11
N2	34.76	37.91	-3.15

EERI

The average P and N2 scores for EERI test, given both pre-intervention and post-intervention, is given in Table 4. Notably, in both the pre- and posttests, both scores are considerably higher than the corresponding DIT-2 scores. The reason behind this phenomenon is one that is not entirely understood, however there is evidence [12] that it has to do with the situated nature of the EERI test when given to engineers (i.e. engineering students are more primed for taking the EERI which is explicitly about engineering phenomena, than the DIT-2, which is generalized). The statistical difference is confirmed also by the analyses in Table 4. Effect sizes were included in the analysis to measure the magnitude of the intervention effect. Because sample sizes are small, a variant of the typical Cohen's *d* called Hedges' G was used. This formula is similar to Cohen's *d* but incorporates an adjustment, which removes the upward bias that is prevalent in smaller samples. Independent sample t-tests were the primary method for comparison.

Table 4. Summary Statistics, Mean (*SD*) for EERI and DIT-2 tests

	n	**P-score**	**N2-score**
EERI pretest	34	56.56 *(17.80)*	54.32 *(17.90)*
EERI post-test	28	51.71 (*21.99*)	53.57 (*22.11*)
DIT-2 post-test	30	39.20 (*16.00*)	37.91 (*14.52*)

Table 5. Comparative Analysis for P and N2 scores

Comparison	***t***	***p-value***	**G**
EERI P pre vs. post	0.941	0.351	0.242
EERI N2 pre vs. post	0.145	0.886	0.037
EERI P vs. DIT-2 P	2.46	0.017*	0.655
EERI N2 vs. DIT-2 N2	3.17	0.0027*	0.844

*Significant at an a α=0.05

Perhaps more importantly, there is a slight downshift in the EERI scores from pre- to post, that on the surface appears to negate the hypothesis that targeted interventions increase moral reasoning skill. However, upon statistical analysis, Hedges' G for the effect on P-score in the EERI is 0.24, indicating a small effect, and for the N2, the score is 0.037, indicating no meaningful effect at all, statistically or otherwise. This phenomenon was puzzling and slightly concerning from an educational standpoint, as typical effect sizes for ethical interventions (when measured for DIT-2 and EERI) are in the moderate range [12]. However, upon further inspection, a possible explanation was found and is described below.

Table 6 presents the total percentage of ranked statements from the EERI pre- and posttests, broken down into their stage classifications. Between the pre- and posttests, there is a slight shift towards including more maintain norms (stage 4) statements and slightly less of the self-interest (stage 2/ 3) and post conventional (stage 5/ 6) statements. As mentioned above, when calculating the P-score, only the number of ranked post-conventional statements is counted. Therefore, students choosing more maintain norms statements than in the pretest easily explain the downshift in P-score. These data may also explain the relative lack of change in the N2 score, since the N2 combines the number of self-interest and maintain norms statements chosen and subtracts it from the number of post conventional statements chosen.

Table 6. Percentages of Self-Interest, Maintain Norms, and Post-conventional ranked choices in the EERI pre- and posttests

	% Self Interest	% Maintain Norms	% Post-conventional
EERI Pre Test	16	34	50
EERI Post Test	14	39	48

It is still unclear why there was so little change in the scores and why students are shifting more towards answers that maintain norms. One possible explanation involves the particular weight that was given during the semester to the application of professional codes of engineering ethics. In the lecture materials and in the homework assignments, a heavy emphasis was placed on awareness of the professional codes of ethics that engineers are held to. Students were asked to reference specific ethical codes when justifying their ethics assignment solutions and they were encouraged to investigate the codes of ethics specific to their majors.

Focus Group Feedback

The focus group, while small (n=2), provided some valuable feedback about the course interventions and the test instruments. When asked about the effectiveness of the in-class activities, the students responded positively to the lecture material and to the in-class case study analysis. Outside of class, the students found the GameLab and ethics case study analysis projects most helpful, quoting specifically that they valued GameLab's ability to provide them with detailed feedback on their submissions. They found the ethics case study analysis to be well laid out and clearly delineated the process they needed to follow to engage in an ethical analysis.

As to the ethics instruments, these students did not feel that it was easier to answer the questions on either instrument after the interventions. They did however feel that their thought processes were more ethical the second time. In particular, the first time through the EERI their approach was more focused on following necessary (civil) laws. The second time through the survey, they took more time to complete it and were not as quick to make decisions. They also felt that they read more deeply into the questions the second time taking the test. Additionally, the participants claimed not to have changed any of their decisions based from the lists of statements provided but did feel that these statements made them think more. After having completed the instruction, they felt that they have a better understanding of the different kinds of ethical implications.

Conclusions and Next Steps

This pilot study sought to evaluate the moral reasoning capability of freshman engineering students with the aim of differentiating between their moral decision-making skills prior to and after exposure to a set of engineering-specific ethics instructional interventions. With regard to the moral baseline of our population of freshman engineering students, this study may suggest that engineering students do not differ significantly in their moral outlooks from their non-engineering undergraduate peers (freshman level through senior), and in fact may be better equipped to tackle moral and ethical questions than the average freshman student in a technical or professional major.

However, it was found that the ethical interventions did not necessarily increase student's ethical decision making or moral responsibility (but maybe had other effects). The slight decrease in P scores (small effect) may indicate that the program's large emphasis on ethical codes is having an impact on the way students think about solving ethical issues, at least in the short term. These implications are borne out in the results of the focus group, which may indicate that the instructional methods prompted deeper thinking about ethical issues, even if student's answers did not change much.

Another major finding was that engineering students scored significantly higher on the EERI than the DIT-2 (small p values and moderate/large effect sizes). This phenomenon may be explainable by the situational nature of the EERI, in which students are exposed to exclusively engineering-specific situations. However, the hypothesis that engineering students are better primed for a targeted test such as the EERI needs to be investigated with a larger pool of subjects.

Next Steps

This pilot serves as a test run for a longer longitudinal study of ethical and moral reasoning utilizing the DIT-2 and EERI tests that the authors plan to initiate in the Spring of 2019. Based on the comments from the focus group and other in-class observations, the ethical interventions and testing scheme will be continually modified moving forward. This study has brought to light several questions for further research:

1.) Do engineering students perform better on the EERI than the DIT-2 in general?
2.) How do EERI/DIT-2 scores change as a student progresses through their education?
3.) Can we as instructors devise better, more testable approaches to ethics education for engineers?

Acknowledgements

The authors would like to thank Dr. Cheryl Bodnar for facilitating the focus group and for her encouragement throughout this project. We would also like to thank Dr. Carla Zoltowski for the many helpful conversations about the EERI & DIT-2.

This research study was funded by the Experiential Engineering Education Department at Rowan University.

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