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Engineering Ethics Through High-Impact Collaborative/Competitive Scenarios (E-ETHICCS): Initial Results and Lessons Learned

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Abstract

Ethics education has been recognized as increasingly important to engineering over the past two decades, although disagreement exists concerning how ethics can and should be taught in the classroom. With active learning strategies becoming a preferred method of instruction, a collaboration of authors from four universities (University of Pittsburgh, University of Connecticut, Rowan University and New Jersey Institute of Technology) are investigating how *game-based or playful learning with strongly situated components* can influence first-year engineering students' ethical knowledge, awareness, and decision making.

This paper offers an overview and results of the progress to date of this three year, NSF Improving Undergraduate STEM Education (IUSE) grant that aims to (1) characterize the ethical awareness and decision making of first-year engineering students, (2) develop game-based learning interventions focused on ethical decision making, and (3) determine how (and why) game-based approaches affect students' ethical awareness in engineering and the advantages of such approaches over non game-based approaches. Now in its second year, the authors have conducted a preliminary analysis of first-year students' ethical knowledge and organization via a concept mapping approach and have measured students' ethical reasoning using the Defining Issues Test 2 (DIT2) and Engineering Ethics Reasoning Instrument (EERI). Further, the authors have developed a suite of ethics-driven games that have been implemented across three of the universities, engaging over 400 first-year engineering students. Evaluation data has also been gathered for further game development and to assess initial student engagement and learning.

Year 1 has provided insight into where first-year engineering students "are at" in terms of ethical knowledge and reasoning when they come to college, and how game-based instruction can be effective in the development of these students into moral agents who understand the consequences of their decisions. Further results from this investigation will provide the engineering education community with a set of impactful and research-based playful learning pedagogy and assessment that will help students confront social and ethical dilemmas in their professional lives.

Introduction

[Sections labeled "Introduction" and "Overview of the Work" are reprinted from the 2021 ASEE Poster Session Paper which provides preliminary material for the reader.] [1]

Over the past twenty years, there has been a strong shift in the scope of US undergraduate engineering programs towards heightening students' awareness of the professional, social and ethical aspects of the profession. The impetus for this shift has come largely from professional societies and sources of accreditation (such as ABET) in response to numerous high profile engineering failures that have underscored the ethical implications of engineering in the broadening cross-cultural context. Many of these widely publicized failures of complex engineering systems can be traced back to lapses in judgment on either ethical or societal impact axes, including the Volkswagen Diesel Engine scandal, the BP Gulf Oil Spill, the Challenger and Columbia space shuttle disasters, the Flint, Michigan Water Crisis, the Florida International University Bridge Collapse, and the Boeing 737-MAX accidents [2-8]. There is NSF-sponsored research that suggests that emphasizing the local and social impact of engineering, and particularly its contributions to health, happiness and safety, may have an important role in attracting and retaining prospective engineers [9]. Even though more ethical skills training interventions are being developed across the US engineering curricula, many engineering programs still do not address these socially impactful issues in formal ways in their curricula.

This multi-phase research initiative aims to both measure and influence early-curriculum engineering students' ethical awareness and reasoning through the use of game-based educational interventions with strongly situated social components. We believe that situating the exploration of engineering ethical challenges and reasoning in a game-based context is a novel way of influencing how students perceive and react to ethical dilemmas. Giving students the opportunity during their education to recognize the wider social and ethical impacts of the profession - through multimedia simulation, role-playing games, case-based learning, and review of other, fictionalized cases - can give them opportunities to reflect on the need to identify complex situations in future settings, as well as a safe environment in which to explore, make mistakes, and discuss the ramifications of various decisions in authentic contexts. Ultimately the goal is to better prepare young engineers to tackle current and future challenges that have tended to be underemphasized in traditional engineering curricula.

The overall research question for this project is "*In what ways can experiential, game-based approaches to engineering ethics improve students' ethical reasoning skills?"* The authors have developed a suite of game-based ethical interventions for use in undergraduate engineering classrooms (virtual or otherwise) that incorporate different mechanisms of play and timescales and provide students with multiple opportunities and ways to engage course materials. Observational studies of the student play experiences within the context of engineering ethical reasoning will be

undertaken to further explore student thought processes and approaches to ethical scenarios. In addition, these interventions will be paired with a mixed-method, within-groups, change-over-time evaluation and assessment strategy for determining ethical awareness and reasoning ability and the impact the interventions have on various learning outcomes. This paper provides an overview of the research endeavor, a description of the games developed, preliminary assessment results, lessons learned, and next steps.

Overview of the Work

There are three primary objectives of this research project:

1. Characterize the ethical reasoning of first-year engineering students in scenarios specific to the engineering profession.
2. Develop several game-based learning interventions focused on ethical reasoning for first year engineering students.
3. Determine how game-based vs. non game-based approaches affect students' ethical reasoning in engineering.

To-date, the project has focused on two parallel goals: preliminary evaluations of students' baseline thinking regarding ethical and moral reasoning (Objective 1) and development and refinement of the game interventions to be used in the studies (Objective 2). Figure 1 outlines the first year of the project and the sections below provide additional detail on the objectives that were addressed.

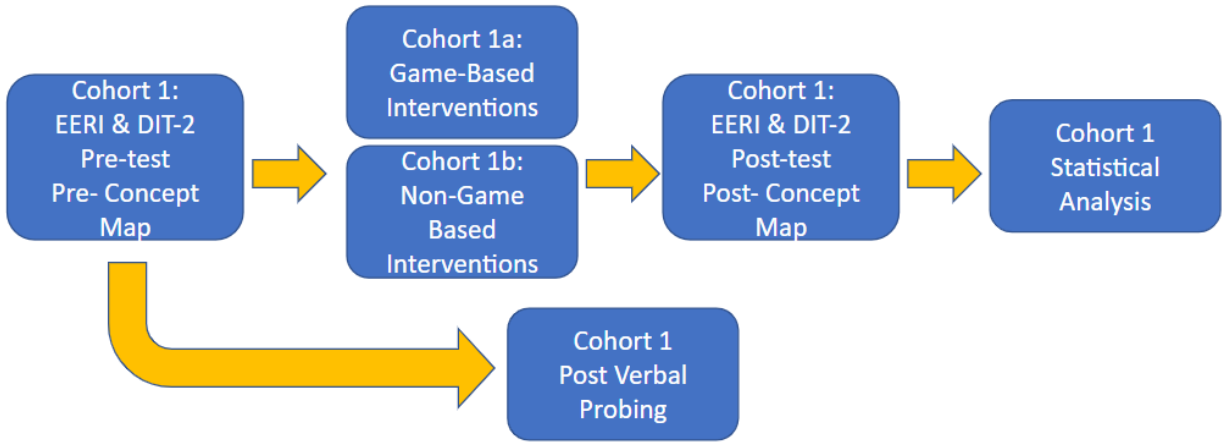

Figure 1. Research Overview (Year 1)

Objective 1 - Evaluations of Baseline Student Ethical Reasoning: Prior to exposure to any ethical instruction, students at participating institutions completed surveys designed to quantitatively measure their ethical reasoning, both generally and within an engineering context. For general moral and ethical reasoning, students took the Defining Issues Test (DIT-2) [10]. For

engineering-specific ethical reasoning, students took the Engineering Ethics Research Instrument (EERI), designed by researchers at Purdue University. [11]

In the Fall 2020 semester, students at participating institutions participated in the development of an ethical reasoning concept map exercise, where they used the CMap software to design a concept map focused on their understanding of factors that contribute to ethical decision making. An expert concept map was created via the research team via the Delphi Method [12]. A research paper on the preliminary analysis of the concept mapping exercise was presented at the 2021 ASEE meeting [13].

In the Spring 2021 semester, students at participating institutions were recruited to participate in group discussions or "post verbal probing" around engineering ethical scenarios derived from the EERI and the Toxic Workplaces: A Cooperative Ethics Card Game (developed by the authors, detailed below).The questions posed to the student groups center around primary morality concepts such as integrity, conflicting obligations, and the contextual nature of ethical decision making. A work-in-progress paper on the research protocol and preliminary results is being presented at the 2021 ASEE meeting [14].

Objective 2 - Develop Game-Based Learning Interventions Focused on Ethical Reasoning and Decision Making: Three different game-based interventions have been designed and refined since the start of the grant period. As this time period coincided with the start of the COVID-19 pandemic and most if not all of the instruction at the participating institutions was moved to an online environment; significant work was done to adapt the gameplay and deployment of all of the games to reflect this reality. Long term, the online modality option will allow for greater flexibility and choice in the dissemination of the game materials to the larger community. A full paper on the details of the game-based interventions is being presented at the 2021 ASEE meeting [15]. A short description of each game can be read below.

1. **Cards Against Engineering Ethics (CAEE)**: Designed as an analog to the popular card games *Cards Against Humanity* and *Apples to Apples*, CAEE contextualizes it's card choices within an engineering ethical framework. Prompt cards and response cards draw from literature and cultural sources of engineering ethical dilemmas, as well as personal experiences of the research team. Play is dynamic, and can be accomplished in groups of varying size and for varying amounts of time, allowing it to be deployed in a classroom setting or given as an out-of-class assignment. For in-person play, cards are printed and distributed to students, and for online play, the game has been ported to an online portal (https://not.allbad.cards/), which allows the game to be played among participants virtually, wherever they may be.

2. **Toxic Workplaces:** Toxic Workplaces is a scenario-based card game which requires the players to evaluate an engineering ethics dilemma, and then collaboratively evaluate potential responses to that scenario. Different responses are given on individual cards, and the goal of the players is to collectively negotiate the ordering of the responses, from least likely to be chosen to most likely. Once the players have ordered all the responses for a scenario, the cards are flipped over to reveal the actual percentages, and scoring occurs, with higher scores given when the player-chosen ordering most closely matches the actual ordering by percentage. The format of this game encourages collective discussion of the scenario and the potential actions, as well as discussion of potential conflicts that emerge when the player-chosen ordering differs from the actual ordering of the responses. This game has also been ported to an online format using Google Slides to allow players to manipulate shared tokens in a collectively accessed document to allow for online play.

3. **Choose Your Own Adventure (CYOA): Mars - An Ethical Expedition:** As compared to the other two games, the CYOA game unfolds over a series of weeks in a narrative arc. Each week students are presented with an ethical dilemma contextualized within the narrative of the students being a new engineering team arrived on Mars as part of a colonization expedition. The narrative arc can evolve and present different choices to students based on the collective response to the weekly scenario, which students will provide via student-response software (i.e. clickers) or via their learning management system (LMS). In Fall 2020, a student team at one of the grantee universities worked on development of this game and ported it to an online portal (https://twinery.org/).

All of these versions of the games were used during the Spring 2021 and Spring 2022 semesters in various combinations at the participating institutions.

Lessons Learned to Date

We are currently in Year 2 (mid-point) of our overall research agenda. We have made progress and gained valuable insight regarding the two primary objectives of the grant - preliminary evaluations of students' baseline thinking regarding ethical and moral reasoning (Objective 1) and development and refinement of the game interventions to be used in the studies (Objective 2). This section provides a summary of the lessons learned at this point in the project:

Objective 1 - Evaluations of Baseline Student Ethical Reasoning: As described above, establishing a baseline measure for engineering students' ethical knowledge and reasoning is imperative to better understand the impact playful learning can have in this area. In the Fall 2020/Spring 20201, the DIT-2 pre and post assessment was collected from a sample of students from both Rowan University and the University of Pittsburgh (Pitt). A total of 440 students (331 Pitt and 109 Rowan) responded to the pretest and only 237 students (198 Pitt and 39 Rowan) responded to the post test.

When paired together there were a total of 210 responses (174 Pitt and 36 Rowan) that could be analyzed. The EERI was used in a similar way with a pre and posttest, but this test was administered to students from Rowan and the University of Connecticut (UConn). A total of 425 students (83 Rowan and 342 UConn) responded to the pretest while 217 students (48 Rowan and 169 UConn) responded to the posttest. When paired together there were 175 usable pairings (32 Rowan and 143 UConn).

The results of this initial analysis suggest that engineering students are coming to college with a fairly standard level of ethical reasoning (when compared against prior work and other established norms). The difference in ethical reasoning between male and female students that is found to be significant for both P and N2 scores of the DIT-2 is consistent with previous research. It had been found that females scored significantly higher on the DIT-2 in and out of the field of engineering. We have found that females are scoring significantly higher on both measures of the EERI. When looking at the changes in ethical reasoning after formal engineering ethics instruction (either via games or through more traditional approaches like case studies), no significant change was found and effect sizes were all quite low. This may indicate a few things: (1) a first-year student's ethical reasoning does not change much over the course of a semester or even academic year. Ethical reasoning may be a measure that is better framed in a longitudinal study, which we are planning to conduct; and (2) if there are changes in how a student reasons through ethical dilemmas, the DIT2 and EERI may not be sensitive enough to detect these changes. Nor are these instruments the correct 'type' for assessing changes in ethical knowledge and reasoning when games are the primary form of instruction.

The concept maps were analyzed using traditional scoring using the CmapParse software [16], holistically scored using a rubric based on comprehension, correctness, and organization [17], and textual analysis of the words used within the concept map. Initial results indicate engineering students understand many concepts related to ethics, they struggle with how those concepts are connected to each other. Most students used concepts like "moral", "right", and "wrong", and focused on words/concepts related to "personal ethics" instead of "professional ethics", a distinction that is important for engineering ethics instruction, especially in the first-year. When looking at the changes in students' ethical knowledge via concept maps before and after ethics instruction, students in game-based sections used more words related to the "impact" of the decision, where the students in more traditional classrooms focused on laws. So while game-based and/or playful learning doesn't appear to have much of an effect on ethical reasoning, it does alter their conceptions of ethics more abstractly. And students were mostly positive about the use of games to teach engineering ethics overall, which can lead to higher levels of engagement and learning. It is worth noting that we did not find much evidence to support the broader use of games to teach engineering ethics (yet).

We also looked at the relationship between DIT2/EERI scores and how students "scored" on the concept maps, both through traditional and holistic means. The initial analysis revealed very little correlation between these measures for a particular student, which is both disappointing but also very revealing. Clearly, the concept maps are ethical reasoning instruments are measuring different things (ethical knowledge in the abstract vs ethical reasoning in highly situated contexts, respectively). It is our understanding that engineering students (at least in the FY) are not seeing ethics abstractly as being connected to ethical reasoning in context. This is a future area of inquiry and the team is currently working on a journal paper that explores this phenomenon more critically.

Results from our group discussions that were conducted with first-year engineering students from Rowan, Pitt, and Uconn in Spring 2021 and Fall 2021 can be found in our upcoming work-in-progress paper and presentation at the ASEE 2022 annual meeting titled *"Talk (Engineering) Ethics to Me: Student Group Discussions about Ethical Scenarios".*

Objective 2 - Develop Game-Based Learning Interventions Focused on Ethical Reasoning and Decision Making: The games used in Year 1 of the grant went well but we noticed a few changes that needed to be made for Year 2. These were mostly to do with making the instructions clearer, organizing the materials, and brainstorming ways to modify the games to require less management and upkeep (especially as we start to share the games with those outside of the research team). This includes a stand-alone, shorter version of Mars: An Ethical Expedition, where faculty and students can play with a smaller team and at their own pace.

We are also including a new instrument aimed specifically at assessing students ethical reasoning/thought process after they have played the games. This instrument is being developed by the research team, but will be informed by past work on assessment tools specifically for game-based instruction. It is our hope that a product of this grant includes an assessment tool specific for playful learning in engineering ethics. We are piloting this instrument in Spring 2022, and it consists of the following types of questions:

- Open-ended questions about their curiosity about engineering ethics
- Evaluations of ethical scenarios and whether the student recognizes that one exists and what that ethical issue entails
- Likert scale questions on their desire to learn more about engineering ethics and the importance of ethics in the engineering profession
- Scale ranking questions on the amount of playful learning and engagement in engineering classrooms

Current and Future Work

As mentioned, we are collecting more data in Year 2 for both concept maps and ethical reasoning measures. The concept map activity that results has been modified to help students better

understand what a concept map is and gives them a chance to practice making a concept map on another engineering/science related topic "photosynthesis". This will hopefully help control for variation in students ability to create concept maps in the first place, resulting in maps that are more representative of the students' knowledge and not their prowess with concept maps and the technology. We also changed how we are administering the DIT2 and EERI. Because we feel these instruments are not sensitive enough to pick up on changes in students ethical reasoning (if changes exist), we are only using them to get a baseline measure of their ethical reasoning, but are no longer using it for pre-, post-tests with the gaming interventions. Instead, we will conduct a longitudinal student to gauge how engineering students' ethical reasoning changes over time and what types of experiences change that trajectory. The following assessment plan is being followed in Year 2:

- Fall semester – DIT2/EERI + Concept Maps + Group Discussions
- Spring semester – gaming interventions and post-survey using the pilot survey described above + Group Discussions

In future years, we will continue to collect data on students' baseline levels of ethical knowledge and reasoning. More qualitative data via group discussions will be gathered pre and post games, and observations of students playing the games will also be explored.

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