

Board 269: Engineering Ethics through High-Impact Game-Based Ethical Interventions: Design and Playful Assessment

Dr. Daniel D. Burkey, University of Connecticut

Daniel Burkey is the Associate Dean of Undergraduate Programs and Professor-in-Residence in the Department of Chemical and Biomolecular Engineering at the University of Connecticut. He received his B.S. in chemical engineering from Lehigh University in 19

Dr. Scott Streiner, University of Pittsburgh

Scott Streiner is an Assistant Professor in the Industrial Engineering Department, teaches in the First-Year Engineering Program and works in the Engineering Education Research Center (EEERC) in the Swanson School of Engineering at the University of Pittsburgh. Scott has received funding through NSF to conduct research on the impact of game-based learning on the development of first-year students' ethical reasoning, as well as research on the development of culturally responsive ethics education in global contexts. He is an active member of the Kern Engineering Entrepreneurship Network (KEEN), the Institute of Industrial and Systems Engineers (IISE), the American Society for Engineering Education (ASEE), and serves on the First-Year Engineering Education (FYEE) Conference Steering Committee.

Dr. Kevin D. Dahm, Rowan University

Kevin Dahm is a Professor of Chemical Engineering at Rowan University. He earned his BS from Worcester Polytechnic Institute (92) and his PhD from Massachusetts Institute of Technology (98). He has published two books, "Fundamentals of Chemical Engineer

Dr. Richard Tyler Cimino, New Jersey Institute of Technology

Dr. Richard T. Cimino is a Senior Lecturer in the Otto H. York Department of Chemical and Materials Engineering at New Jersey Institute of Technology. He received his Ph.D in Chemical & Biochemical Engineering from Rutgers University. His research interests include engineering ethics and process safety, and broadening inclusivity and belonging in engineering, especially among the LGBTQ+ community. His funded research has explored the effects of implicit bias on ethical decision making in the engineering classroom and gamification of engineering ethics education.

Dr. Jennifer Pascal, University of Connecticut

Jennifer Pascal is an Assistant Professor in Residence at the University of Connecticut. She earned her PhD from Tennessee Technological University in 2011 and was then an NIH Academic Science Education and Research Training (ASERT) Postdoctoral Fellow at

Engineering Ethics Through High-Impact Game-Based Ethical Interventions: Design and Playful Assessment

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 the support from the National Science Foundation (NSF) Improving Undergraduate STEM Education (IUSE) program, a collaboration of investigators from the University of Connecticut, New Jersey Institute of Technology, University of Pittsburgh, and Rowan University are conducting a mixed-methods project investigating how game-based or playful learning *with strongly situated components* can influence first-year engineering students' ethical knowledge, awareness, and decision making. We have conducted preliminary analyses of first-year students' ethical reasoning and knowledge using the Defining Issues Test 2 (DIT-2), Engineering Ethics Reasoning Instrument (EERI), and concept map assessment to characterize where students "are at" when they come to college, the results of which can be found in past ASEE publications. Additionally, we have developed a suite of ethics-driven classroom games that have been implemented and evaluated across three universities, engaging over 400 first-year engineering students. Now in its third year, we are modifying and (re)designing two of the game-based ethics interventions to (1) more accurately align with the ethical dilemmas in the EERI, (2) allow for more flexibility in modality of how the games are distributed to faculty and students, and (3) provide more variety in terms of the contexts of ethical dilemmas as well as types of dilemmas. As part of the continued development of the game-based ethical interventions, we are piloting a new assessment tool specific for playful learning in engineering ethics and aimed at measuring students ethical reasoning and thought process after they have played the game(s).

The past year has provided insight into the potential limitations of the existing methods for measuring changes in ethical reasoning in students, as well as compared changes between first year and senior students. The last year has highlighted the situated or contextual nature of much of the ethical decision making that students do and incorporated both qualitative and quantitative methods. 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).

Objective 1 - Evaluations of 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 Spring 2022 and Spring 2023 semesters, both first year and senior students at a subset of the participating institutions took the EERI instrument. For first-year students this was the continuation of baseline evaluation of ethical reasoning. For seniors, this was to compare to the same data taken in the first year to evaluate any longer-term longitudinal changes in ethical reasoning that occurred over the course of the entire collegiate experience. Additionally, a comparison of data obtained from the EERI and data obtained from the student playthrough of the Mars: An Ethical Adventure game were compared both qualitatively and quantitatively, with results presented at the 2022 FIE Conference in Uppsala, Sweden. [12]

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 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 its card choices within an engineering ethical framework. Prompt cards and response cards draw 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 Winter 2022, the Mars game was ported to a voice-acted podcast-style delivery, and in Winter 2023, has been ported to the Godot platform. (<https://godotoengine.org>)

All of these versions of the games were used during the Spring 2021, Spring 2022, and Spring 2023 semesters in various combinations at the participating institutions.

Lessons Learned to Date

We are currently completing Year 3 of the grant. Due to delays caused by COVID, the research team applied for and has been granted a no-cost extension to complete the work. In the past year, we have focused on developing a deeper understanding of the challenges in assessing changes in student ethical reasoning, as well as continuing development and refinement of the game-based interventions especially the Mars: An Ethical Expedition game. We also have disseminated the work in a variety of venues, sharing what has been learned about assessment of ethical reasoning as well as the games themselves with broad audiences.

Objective 1 - Evaluations of Student Ethical Reasoning: The research team has deployed combinations of the EERI (Engineering Ethical Reasoning Instrument) and the DIT-2 (Defining Issues Test) to a mix of students at the participating schools over each of the past four spring semesters: Spring 2020, Spring 2021, Spring 2022, and Spring 2023. This has provided ample opportunity to gather baseline information about first-year engineering student ethical reasoning over numerous cohorts.

As described in last year's update, the results of these studies have found that the students participating are performing, at baseline, approximately the same as other students in their age and demographic range in terms of their quantitative score on instruments such as the EERI and DIT-2. Analysis of surveys completed both before and after the introduction of the game-based ethical educational interventions have not shown significant differences: changes in ethical reasoning after formal engineering ethics instruction (either via games or through more traditional approaches like case studies) show no significant changes and effect sizes are all small.

Since student ethical reasoning as measured by these instruments seems stable over the course of single semester, we planned to collect follow-up data from senior engineering students to see if there were any changes over the course of their college academic career. In Spring 2022 we collected 33 EERI responses from senior engineering students, a subset of which we were able to pair with responses from their first year to examine changes. Overall, this subset of students did not show statistically significant changes in their EERI scores between first year and senior year. While the sample size for this cohort is too small from which to draw a reliable conclusion, it does suggest that the EERI and DIT-2 measurements may be extremely stable over time and that they are potentially not well-suited to assess *changes* in student ethical reasoning as a result of educational interventions. The research team is currently re-running this study with a different recruitment approach for seniors to increase the sample size to draw more meaningful conclusions.

The use of the Mars: An Ethical Adventure game also provided a valuable insight into how students approached ethical reasoning. The Mars game presents students with a coherent narrative arc that

poses weekly ethical dilemmas that are contextualized within the story context. These ethical scenarios can be deconstructed into their core dilemmas. This was done for each of the 12 weeks of the Mars narrative, as well as for each of the scenarios from the EERI instrument. Scenarios that had common core dilemmas could then be compared to determine how students' responses varied depending upon the specific context of the dilemma.

Results from this mixed-methods analysis showed that student responses to the same core dilemma varied considerably based upon the specific context in which the dilemma was presented, which suggests that student ethical reasoning can be highly situated in these contexts, and thus presenting them with static scenarios such as the EERI might not be fully capturing the range and variability of their thinking. It was interesting to note that student responses matched their EERI response best when the Mars ethical dilemma in question was the most abstract and differed more extremely the more the scenario became well defined and included elements of personal involvement. This again suggests that the students' ethical reasoning may be highly situated and that they view the EERI and similar instruments as abstract or non-personal "tests" of engineering ethics and the narrative, game-based approach of the Mars game allows more immersion, and thus more authentic responses. This has implications for how engineering ethics is both taught and how it is assessed. The research team presented these findings at the Frontiers in Education conference in Uppsala, Sweden, in Fall 2022.

Objective 2 - Develop Game-Based Learning Interventions Focused on Ethical Reasoning and Decision Making: Development of the games has continued based on feedback from the students as playtesting has continued in each semester. Cards Against Engineering Ethics is updated regularly with new card content based on crowdsourcing responses from the students each semester and is available as both a physical game as well as a web-based game. Researchers at [University Name] have involved the students in a project-based class to develop and pilot test additional scenarios and responses. The gameplay itself for both of these games has remained largely stable and the research team is content with the current state of their ruleset and play deployment. These games have both been shared with colleagues around the nation following their inclusion in talks and workshops in the past year. Feedback from faculty and institutions that ask to use these materials is part of the standard ask when sharing the materials.

Toxic Workplaces has been integrated into first year, introductory engineering classes at several different universities. The number of different scenarios that had been used prior to the start of the current academic year was less than 10. During the Fall 2022 semester, a team of 8 junior and senior engineering students representing four different engineering disciplines (Electrical & Computer, Mechanical, Civil, Chemical) participated in a project in which the students authored new scenarios for use in Toxic Workplaces. The project was integrated into the Junior/Senior Engineering Clinic, a two-credit project-based course that is required for students in all engineering disciplines at [University Name].

The goal of the project was not only to expand the range of options available to the instructor, but also to broaden the range of courses for which Toxic Workplaces is well suited. Thus far, Toxic Workplaces has only been used in introductory engineering courses that are multi-disciplinary in nature. In this context, most any scenario that included a compelling ethical dilemma would be suitable. However, engineering ethics instruction also occurs in disciplinary engineering courses. The student team's goal was to ensure that the bank of available scenarios would include at least 3-4 that were clearly related to each of the engineering disciplines, so that they would seem more relatable to students taking a class in that discipline. In all, 24 new scenarios were crafted, with each student on the team serving as the primary author of three. The details of this development can be found in a paper submitted to the 2023 ASEE Annual Conference and Exposition titled "Work in Progress: Toxic Workplaces: Game-Based Exploration of Engineering Ethics for First Year Engineering Students [13]".

The Mars: An Ethical Expedition game has undergone the most significant changes in the past year. Originally, the narrative was read in-person prior to the start of each class period and students were asked to then register their decisions on the ethical dilemmas electronically, either via software such as PollEverywhere or later, Qualtrics. To include both more multimedia and more diversity, in the Spring 2022 semester the Mars game was re-done using a diverse cast of audio actors and sound effects, creating a more complete narrative experience. The individual episodes were released, podcast style, once a week to students through the learning management system (LMS). The downside to this approach was that the next week's audio could not be completed until the current week's decision was known, as it impacted the flow and evolution of the story.

To overcome this challenge, the Godot game engine (<https://godotengine.org>) was used to create a stand-alone app (Mac and Windows) for the Mars game that incorporated all the possible audio files and outcomes. The game engine allows the choices that students make on a weekly basis to connect via the engine logic to the correct audio files and questions that correspond to the student's choices. In this way, each student can have an individual and unique playthrough of the narrative that is not dependent upon crowdsourcing of the course of action. This has implications for our current and future work in understanding the processes that students use to make these types of ethical decisions, both collaboratively and individually. Further details for Mars: An Ethical Expedition can be found in a paper submitted to the 2023 ASEE Annual Conference and Exposition titled "The Power of Playful Learning – Ethical Decision Making in a Narrative-Driven, Fictional, Choose-Your-Own Adventure [14]".

Current and Future Work

Current work involves quantitative analysis of the first-year and senior EERI data to examine longitudinal changes in student ethical reasoning. The pivot of the Mars game to the Godot platform has allowed the research team to deploy the game in various ways. In the Spring 2023

semester, one cohort is being presented with the game collectively, with a facilitator playing the game and the students collectively making the decision about the next steps, while the other cohort is playing the game fully individually. We hope to understand what the potential impact is of collective versus individual decision-making is, and how this shapes the outcomes in ethical dilemmas. In the final year of the grant we plan to fully analyze the longitudinal data for the EERI assessment and continue to use the Mars game for exploring situated and contextual decision making, as well as collaborative vs. individual decision making. By the completion of the grant, all three games will be available for educators to use upon request.

Acknowledgements

This research is being funded by the National Science Foundation, “Collaborative Research: Learning Engineering Ethics Through High-Impact Collaborative and Competitive Scenarios” (IUSE – 2211320 and 1934707).

References

- [1] S. Streiner, D. Burkey, M. Young, R. Cimino, & J. Pascal, “Engineering Ethics Through High-Impact Collaborative/Competitive Scenarios (E-ETHICCS).” ASEE Annual Conference and Exposition, Long Beach, CA, July 2021
- [2] P. Patel, “Engineers, Ethics, and the VW Scandal,” IEEE Spectrum, 25 Sept. 2015. [Online]. Available: <http://spectrum.ieee.org/cars-that-think/at-work/education/vw-scandal-shocking-but-not-surprising-ethicists-say>. [Accessed Apr. 11, 2019].
- [3] M. Hart, “The Ethical Lessons of Deepwater,” ASME.org, March 2011. [Online]. Available: <https://www.asme.org/engineering-topics/articles/engineering-ethics/the-ethical-lessons-of-deepwater>. [Accessed Apr. 11, 2019].
- [4] R.P. Boisjoly, E.F. Curtis, & E. Mellican, “Roger Boisjoly and the Challenger Disaster: The Ethical Dimensions,” Journal of Business Ethics, vol. 8, no. 4, pp. 217-230, 1989.
- [5] H.W. Gehman, Jr., J.L. Barry, D.W. Deal, J.N. Hallock, K.W. Hess, G.S. Hubbard, J.M. Logsdon, D.D. Osherooff, S.K. Ride, R.E. Tetrault, S.A. Turcotte, S.B. Wallace, and S.E. Widnall, “Columbia Accident Investigation Report, Volume I,” NASA, Aug. 26 2003. Available:http://www.nasa.gov/columbia/home/CAIB_Vol1.html.
- [6] S. Bates, “Flint water crisis: For young engineers, a lesson on the importance of listening,” NSF.gov, 23 March 2016. [Online]. Available:

http://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=138060&WT.mc_id=USNSF_1.
[Accessed Apr. 11, 2019].

[7] K. Samuelson, “Companies That Built Collapsed FIU Bridge Had Been Fined for Safety Violations,” *time.com*, 16 Mar. 2018. [Online]. Available: <http://time.com/5203126/fiu-bridge-collapse-safety-violations/>. [Accessed Apr. 11, 2019].

[8] M. Peterson, “The Ethical Failures Behind the Boeing Disasters,” *Blog of the APA*, 8 Apr. 2019. [Online]. Available: <https://blog.apaonline.org/2019/04/08/the-ethical-failures-behind-the-boeing-disasters/>. [Accessed Apr. 11, 2019].

[9] “Engineering The Future, 2008 Annual Report”, *Engineering The Future, 2008 Annual Report*, National Academy of Engineering, [Online]. Available: <https://www.nae.edu/File.aspx?id=43355>. [Accessed Apr. 11, 2019].

[10] Rest, J., Narvaez, D., Bebeau, M., & Thoma, S. (1999). A neo-Kohlbergian approach: The DIT and schema theory. *Educational Psychology Review*, 11(4), 291-324.

[11] Zhu, Q., & Zoltowski, C. B., & Feister, M. K., & Buzzanell, P. M., & Oakes, W. C., & Mead, A. D. (2014, June), The Development of an Instrument for Assessing Individual Ethical Decision Making in Project-based Design Teams: Integrating Quantitative and Qualitative Methods. Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana. 10.18260/1-2—23130

[12] D. Burkey, R. Cimino, M. Young, K. Dahm, & S. Streiner (2022, October). It’s All Relative: Examining Student Ethical Decision Making in a Narrative Game-Based Ethical Intervention. In *2022 IEEE Frontiers in Education Conference (FIE)* (pp. 1-6). IEEE.

[13] K. Dahm, A. Riley, S. Streiner, D. Burkey, R. Cimino, J. Pascal, & M. Young(2023). Work in Progress: Toxic Workplaces: Game-Based Exploration of Engineering Ethics for First Year Engineering Students. Submitted to the 2023 ASEE Annual Conference and Exposition.

[14] T. Wagner, L. Bassett, J. Pascal, D. Burkey, M. Young, & S. Streiner(2023). The Power of Playful Learning – Ethical Decision Making in a Narrative-Driven, Fictional, Choose-Your-Own Adventure (Work in Progress). Submitted to the 2023 ASEE Annual Conference and Exposition.