7-26-2021

Engineering Ethics Through High-Impact Collaborative/ Competitive Scenarios (E-ETHICCS)

Scott C. Streiner
Rowan University, streiner@rowan.edu

Daniel D. Burkey

Michael F. Young

Richard Tyler Cimino

Jennifer Pascal

2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33860

Engineering Ethics Through High-Impact Collaborative/Competitive Scenarios (E-ETHICCS)

Dr. Scott Streiner, Rowan University

Dr. Scott Streiner is an assistant professor in the Experiential Engineering Education Department (ExEEd) at Rowan University. He received his Ph.D in Industrial Engineering from the University of Pittsburgh, with a focus in engineering education. His research interests include engineering global competency, curricula and assessment; pedagogical innovations through game-based and playful learning; spatial skills development and engineering ethics education. His funded research explores the nature of global competency development by assessing how international experiences improve the global perspectives of engineering students. Dr. Streiner has published papers and given presentations in global engineering education at several national conferences. Scott is an active member in the Center for the Integration of Research, Teaching, and Learning (CIRTL) both locally and nationally, as well as the American Society for Engineering Education (ASEE) and the Institute of Industrial and Systems Engineers (IISE).

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 1998, and his M.S.C.E.P and Ph.D. in chemical engineering from the Massachusetts Institute of Technology in 2000 and 2003, respectively. His primary areas of interest are game-based education, engineering ethics, and process safety education.

Prof. Michael F. Young, University of Connecticut

Dr. Young (http://myoung.education.uconn.edu/) received his PhD from Vanderbilt University in Cognitive Psychology and directs UConn's 2 Summers in Learning Technology program. He is the author of nine chapters on an ecological psychology approach to instructional design and has authored more than two dozen peer reviewed research papers. His work has appeared in many major journals including the Journal of Educational Computing Research, the Journal of the Learning Sciences, the Journal of Research on Science Teaching, Instructional Science, and Educational Technology Research and Development. Mike's research concerns how people think and learning, and specifically how technology can enhance the way people think and learn. His NSF-funded project, GEEWIS (http://www.geewis.uconn.edu/), focused on streaming real-time water quality pond data via the Internet and providing support for the integration of this authentic data into secondary and higher education science classrooms. His approach features the analysis of log files, "dribble files," that maintain time-stamped listing of navigation choices and lag time. This approach has been applied to hypertext reading (Spencer Foundation grant), videodisc-based problem solving (Jasper project), and online navigation (Jason project). Recent work concerns playful learning using video game, card games, and board games aligned with national teaching and learning standards.

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 the Rutgers University, with a focus in adsorption science and the characterization of porous materials. His research interests include engineering ethics and process safety, and broadening inclusivity in engineering, especially among the LGBTQ+ community. His previous funded research has explored the effects of implicit bias on ethical decision making in the engineering classroom.

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 the University of New Mexico. Her research interests include the integration of fine arts and engineering and developing effective methods to teach transport phenomena.

Engineering Ethics Through High-Impact Collaborative/Competitive Scenarios (E-ETHICCS)

Abstract

Engineering grand challenges increasingly involve numerous social and ethical considerations that transcend the technical skills that dominate traditional engineering education. Engineering solutions often have major, long-lasting impacts on society. Since the process of technical innovation occurs in increasingly complex social exchanges, engineers are frequently confronted with social and ethical dilemmas in their professional lives. How do students acquire the skills needed to tackle these problems? The authors hypothesize that placing engineering challenges and solutions in a classroom context while emphasizing social engagement and impact facilitates the development of engineering students as moral agents who understand the consequences of their decisions. Thus, a collaboration of investigators from the grantee universities are investigating how game-based educational interventions with strongly situated components influence early-curriculum engineering students' ethical awareness and decision making.

This paper offers an overview 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. Results from this investigation will offer the engineering education community insight into how engineering students approach problem solving through the lens of ethical reasoning and decision making, potentially transforming an often overlooked part of engineering curricula for decades to come.

I. Introduction

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 [1-7]. 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 [8]. 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.

II. 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.

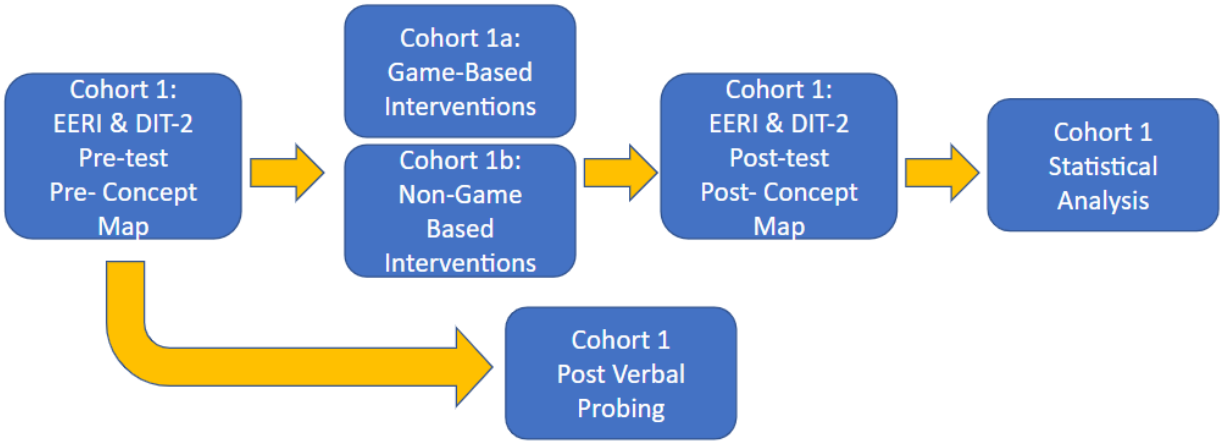

Figure 1. Research Overview (Year 1)

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) [9]. For engineering-specific ethical reasoning, students took the Engineering Ethics Research Instrument (EERI), designed by researchers at Purdue University. [10]

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 [11]. A research paper on the preliminary analysis of the concept mapping exercise is being presented at the 2021 ASEE meeting [12].

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 [13].

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 [14]. 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 are being used during the Spring 2021 semester in various combinations at the participating institutions.

III. Current and Future Work

Current Work: In the Spring 2021 semester, the team began by administering the DIT-2 and EERI to students at the three grantee institutions. This established a baseline of moral and ethical reasoning for students, as well provided points of comparison between the DIT-2, which measures general moral reasoning, and the EERI, which situates the ethical dilemmas in an engineering context. Scoring and analysis of these instruments will continue throughout the Spring and Summer 2021. Near the end of the semester, students will again be administered these instruments to determine what, if any, changes have occurred. Students will also engage in the concept mapping activity at the end of the Spring 2021 semester as another form of assessment to determine if students' conceptualizations around ethical decision making have changed.

In between these two surveys, subsets of students at two participating universities are being exposed to the game-based interventions described above. Students at the third university are not being exposed to the game-based interventions as a control. At the one site, the game-based interventions are being played by approximately 275 out of 450 students in one of two sections of the freshmen engineering design course, with the other section of the course as a control. At the second site, ten out of fourteen sections, representing 180-200 students, are playing the game-based interventions.

Additionally, students at the grantee institutions are being recruited to participate in a group discussion or "post verbal probing" study designed to discover how students reason through the ethical scenarios created for the Toxic Workplaces game. Three to four students in mixed groups across the universities will meet virtually for approximately one hour to discuss various engineering ethical scenarios (see [14] for details regarding the protocol and scenarios). Following these sessions, the data will be coded via an emergent coding methodology to discover what themes are present as students consider the ethical issues in the scenarios.

Future Work: In future years of the research grant, more specific analysis on the impact of the game-based ethical interventions will be explored, including surveys and focus groups that target

particular playful and situated aspects of the games. Further, we will employ observational protocols of the games being played. Observational studies (phenomenography, for example) will be used on the students in classes that include the game-based ethical interventions - to explore the qualitatively different ways in which the students are realizing, conceptualizing, and understanding the various aspects of the play experience. Follow-up debriefing sessions will also be conducted to further elucidate underlying play aspects that may contribute to developing ethical reasoning. Pre/post tests using the EERI and DIT2 will be carried out on game and non-game student groups (similar to Year 1). Demographic analyses of the results will also be performed at this stage to determine how the game-based ethical interventions impact various demographic groups' ethical reasoning. This analysis is important as it has found that game-based learning may impact demographic groups differently and it is critical to create a positive learning environment for all students to learn about engineering ethics [15,16,17,18].

IV. Summary

The research team has successfully developed three game-based approaches to teaching engineering ethics and developing ethical reasoning skills, and has pivoted those three interventions to online play to accommodate the distance learning modalities that many universities find themselves in under the current pandemic situation. Baseline data about student ethical reasoning is being collected via literature-based ethical reasoning instruments, by cognitive interviewing with a verbal probing technique, and via the student development and expert analysis of concept maps focused on ethical reasoning. In addition to these baseline measures, the developed games have been deployed to the participating universities for playtesting with the intended audience of first-year engineering students, and feedback and data collection on these interventions is continuing throughout the spring 2021 semester. Future work will include continued refinement and development of the game-based interventions, as well as additional qualitative and quantitative examinations of how students' ethical reasoning shifts over time and in response to the educational interventions.

Acknowledgements

This research is being funded by the National Science Foundation, "Collaborative Research: Learning Engineering Ethics Through High-Impact Collaborative and Competitive Scenarios" (IUSE – 1934702).

References

[1] 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].

[2] 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].

[3] 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.

[4] H.W. Gehman, Jr., J.L. Barry, D.W. Deal, J.N. Hallock, K.W. Hess, G.S. Hubbard, J.M. Logsdon, D.D. Osheroff, 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.

[5] 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].

[6] 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].

[7] 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].

[8] “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].

[9] 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.

[10] 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

[11] Linstone, H. A., & Turoff, M. (Eds.). (1975). The delphi method (pp. 3-12). Reading, MA: Addison-Wesley.

[12] Reed, J.,Streiner, S., Burkey, D., Cimino, R., Pascal, J., & Young, M., "Mapping the Landscape of First-Year Engineering Students' Conceptualizations of Ethical Decision Making," ASEE Annual Conference and Exposition, Long Beach, CA, July 2021

[13] Bassett, L., Pascal, J., Cimino, R., Dahm, K., Burkey, D., & Streiner, S., "Let's Talk! A Qualitative Analysis of First-Year Engineering Student Group Discussions Around Ethical Scenarios," ASEE Annual Conference and Exposition, Long Beach, CA, July 2021, work-in-progress.

[14] Young, M., Bassett, L., Burkey, D., Streiner, S., & Reed, J., "Let's Play! Gamifying Engineering Ethics Education Through the Development of Competitive and Collaborative Activities," ASEE Annual Conference and Exposition, Long Beach, CA, July 2021

[15] J. Robertson, “Making games in the classroom: Benefits and gender concerns,” Computers & Education, vol. 59, no. 2, pp. 385-398, 2012.

[16] M. Kinzie and D. Joseph, “Gender differences in game activity preferences of middle school children: implications for educational game design,” Educational Technology Research & Development, vol. 56, no. 5/6, pp. 643-663, 2008.

[17] S. Kim and M. Chang, “Computer games for the math achievement of diverse students,” Journal Of Educational Technology & Society, vol. 13, no. 3, pp. 224-232, 2010.

[18] T. Lowrie and R. Jorgensen “Gender Differences in Students' Mathematics Game Playing,” Computers & Education, vol. 57, no. 4, pp. 2244-2248, 2011.