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Let's Play! Gamifying Engineering Ethics Education Through the Development of Competitive and Collaborative Activities

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Through both success and failure, many engineering projects have a profound impact on individuals and society. Thus, ensuring future engineers consider these impacts and reflect on the ethical implications of their future work is an extremely important topic. There are many pitfalls with the traditional large lecture format in which ethics is taught to engineering freshmen. It is taught as an abstract philosophical topic, rather than an act of personal decision making situated in the nuances of complex real-world contexts [1]. Often, engineering ethics instruction is taught by a philosophy professor rather than an engineer. It is usually included late in the undergraduate curriculum, such as during a senior capstone project, and is a relatively short subtopic (module) within a larger array of engineering content. As a result, students often do not see ethics as equally important as other topics. They do not see it consistently integrated throughout the curriculum, nor do they see ethical decisions as complex, nuanced, and situated in the varying political and economic contexts in which engineering takes place.

Certainly there has been ongoing work to construct meaningful and comprehensive ethical guidelines for engineers that must be a resource for all ethics instruction [2]. Events such as the Space Shuttle Challenger disaster have led to revisions of professional codes of ethics to ensure engineers have concern for public health [3]. Taken together these guidelines are designed to ensure engineers consider socioeconomic inequalities, history and geopolitics, as part of the engineering coursework [4]. We assert that ethics education goes well beyond ensuring that freshman engineers are aware of engineering guidelines and codes of ethics. In fact, engineering education often has been seen to value technical over social or ethical competency [5]. Further, there are those who even question if engineers can advance their ethical decision making as they increase their technical knowledge. In a 2020 blog post, UVA professor D. Johnson reported a newspaper columnist's view of difficulties of ethics education:

> *"Worthington expresses a form of skepticism that is not uncommon when it comes to teaching ethics to undergraduate engineering students. For example, Karl Stephan, a professor of*

engineering, described the following encounter: "Some years ago I argued with a fellow professor about the issue of engineering ethics education at the college level. His point was along the lines of, 'Hell, if eighteen-year-old kids don't know right from wrong by the time we get 'em, they're not going to learn it from us.'" [6]

We suggest engineering ethics education should address not only the abstract of philosophy, moral development, or professional guidelines, but also become an interrogation of situated everyday decisions that engineers make as they do their work. Our approach draws on the situated cognition of a community or practice as described by Lave and Wenger [7]. Since such everyday engineering decisions are rarely a part of freshman coursework, the alternative in the context of classes, is to simulate engineering decision-making situations with scenarios or the presentation of ethical dilemmas drawn from real life cases. This can often put students in the position of searching for the "right ethical response," rather than applying their personal ethic toward reasoning through various contingencies and trade-offs to determine their best path to solution in a particular moment. Drawing on the contemporary learning theory of situated learning [7][8], playful learning may enable instructors to create assignments that enable students to break free of the typical student mindset of finding the "right" answer, and use various game mechanisms to induce them to act more as themselves, as they would on-the-fly within a real engineering project context, drawing on personal reasoning and justifications, rather than simply right/wrong answers.

Our work to improve freshman engineer's interrogation of topics in engineering ethics is based on the logic that game-based learning can provide a means to engage students actively in interrogating the complexities of ethical decision making in specific engineering scenarios. Game play can align with engineering course learning objectives as well as enhance student knowledge, behaviors, and dispositions as students reflect on their own decision making and that of their peers [9]. We describe three games that we designed to assist in the development of students' ethical awareness and reasoning in hopes of highlighting the concepts that guide our approach to innovative engineering ethics instruction.

As part of an NSF-funded project investigating the impacts of game play on ethical reasoning and decision making, we developed 3 playful assignments that address various student learning outcomes related to engineering ethics: *Cards Against Engineering Ethics*, *Toxic Workplaces*, and *Mars: An Ethical Expedition*. Each game targets specific ethics learning outcomes and uses different play mechanics. These outcomes included identifying the complexities of ethical dilemmas, evaluating responses to ethical situations in context, and promoting ethical discussions among peers on potentially controversial situations from real-life engineering disasters. The time required to play each game varies, ranging from 20 minutes, to 75 minutes, to 5 minutes once a week for 15 weeks. Initial classroom trials and pilot studies [9] suggest our ethics games can enrich student engagement and reflection, and enable students to detect a greater connection between engineering ethics instruction and their eventual real-life work as engineers. For purposes of this paper, we review the basis for why this work might be productive and detail the frameworks that guided our designs.

Why Try a Playful Approach to Engineering Ethics Instruction?

Game-based educational techniques, including gamification and playful simulations, are increasingly under investigation as an effective way of improving student engagement and learning. Deterding, Khaled, Nacke, and Dixon [10] described gamification as a relatively new term, created by the digital media industry that entered into widespread use only around 2010. In general, it can be thought of as the application of game mechanics (such as incentives, reward systems, and competitive leaderboards) to non-game activities such as formal and informal learning environments. Gamification is one form of playful learning that focuses largely on rewarding players, a process that draws heavily from the Behaviorism framework of learning theory. Gamification has been applied in business training and product marketing, as a way to incentivize employees and engage consumers. As Lee and Hammer [11] pointed out, education, particularly early elementary school, inherently already has many game-like elements consistent with a long-standing appreciation of Behavioral principles of reinforcement and token economies, including points (grades), badges, stickers, and other awards or penalties for desirable/undesirable behaviors.

A number of review articles have recently been written synthesizing the impact of game mechanic elements on both student attitudes as well as achievement measures. Clark, Tanner-

Smith, & Killingsworth [12] synthesized many studies on games in the K-16 educational space across multiple disciplines. Their work, which covered literature on digital games from 2000 to 2012, incorporated work from other meta-analyses on the subject, including those by Sitzmann (spanning from 1976-2009) [13], Vogel, Vogel, Cannon-Bowers, Bowers, Muse, and Wright (spanning from 1986-2003) [14], and Wouters, van Nimwegen, van Oostendorp, and van der Spek (spanning from 1990-2012) [15], all of which demonstrated variable, but overall positive student learning benefits from game-based instruction as compared to comparable non-game instruction. Additionally, they found that the type of game elements incorporated into instruction also had a distinct and significant impact on the student outcomes. A separate review by Young, et al. [5] broadly surveyed the use of video games in the K-12 educational space, and identified over 300 papers that related the use of video games to academic achievement. Their findings emphasized that game-based research must adopt a situated framework to understand how game play impacts each player dynamically and on-the-fly, based on each player's unique goals and intentions during play, rather than averaging across the broad impacts that game mechanics have on student learning. Lastly, a review by Bodnar, Anastasio, Enszer, and Burkey, [16] focused specifically on engineering disciplines in the 2000-2015 time frame, illustrated that game-based instruction in engineering generally had positive impacts on student outcomes, both attitudes and knowledge. Thus, it can be taken that game-based educational tools, when designed and implemented strategically, can produce significant cognitive and attitudinal gains for some students, in some content areas, and in some learning contexts. And it is therefore best understood from a situated cognitive perspective.

Often, much of learning in game play comes from interactions that transpire among players outside game play itself (what can be referred to as the meta-game). For example, many games have companion sites that offer hints, cheats, and expert player advice. In video games specifically it is often possible to watch others play and explain their strategies on Twitch™ and Youtube™ channels. These sites often include the option for readers to socially construct game knowledge by up-voting and down-voting the contributions of others, and thus represent a crowd-sourced guide to (reflection on) game play. Players who read these sites might be seen as learners, while players who contribute posts are akin to teachers. So, engaging students in building and interacting on such meta-game sites could be an important mechanism for enhancing their learning, while also providing a peer-reviewed measure of their achievement within the game—namely, upvoting.

Student work on such meta-game activities may have as much, or more, instructional value as game play itself [5]. Our current NSF sponsored work primarily focuses on initial game design and testing, but supporting professors and students in learning from game play is the next logical step. Designing companions sites for games in which players can collaborate on strategies, outcomes, and other forms of hints and cheats would be a possible trajectory for our continued work.

Many approaches to teaching engineering ethics have been detailed in the literature (for example, see reviews by Hekert [1] and Hess & Fore [17]). One widely used approach is the use of the case study. However, as Adams, Harris, and Carley [18] note in their discussion of case studies, they often deal with macro-ethical topics far removed from individual action, and are often obvious or egregious violations of ethical norms. Lloyd and van de Poel [19] note that the typical engineer would likely never face such clear-cut ethical dilemmas, and that the "chronologically 'neat'" presentation of the case can incorrectly lead students to conclude that ethical decision making is largely straightforward. As a consequence, students can often objectively reason what is "right" to do or discern the best answer from their level of moral development, without ever engaging their everyday cognition to consider what they might really do if it were their own real-life dilemma. One of the main ways in which game-based approaches can succeed is by altering the normal social rules that apply in the educational setting. For example, Xenos and Velli [20] adapted a commercial choose-your-own adventure style digital game to present ethical dilemmas in a computer science context, while Lloyd & van de Poel [19] adapted an engineering design-based board game to include some ethical elements, and situated the game in a fictional 2D-world. LeBlanc [21] suggested that by incentivizing or rewarding useful academic behaviors, like persistence, that students can develop new frameworks for interpreting their educational activities. Playful learning can motivate student engagement, and can also challenge students' self-concepts as learners as they adopt the first person strategy of a player rather than the third person perspective of completing class assignments. From an ethics instruction standpoint, situating ethical discussion within a playful learning framework may allow students to explore "incorrect" answers, (i.e., ones that may know to be unethical or morally wrong, yet reasonable actions they might take in certain circumstances) when those may represent a winning condition within the context of the game. This approach may foster a deeper engagement with the contextual nature of ethical thinking, as students have to defend or explain their choices, or be required to more fully consider all of the potential options and constraints on actions, before selecting the one that would be considered obviously “best” or “correct.”

From a peer learning perspective, game play as a social activity can foster collaboration within groups, as the group can gain benefits through cooperative actions, as well as promote high achievement by fostering friendly competition between groups for rewards (which can be real or just ‘bragging rights’). As Felder, Woods, Stice, and Rugarcia [22] pointed out, cooperative learning is clearly a successful strategy for promoting learning. The playful learning structure also engages multiple types of students, not only the naturally high achievers, as some of the tasks and rewards can be based on activities that are outside the normal grading rubrics. As Locke and Latham [23] pointed out, the ability to provide multiple avenues for success, together with the choice of different tasks to reach larger goals, results in higher engagement and motivation.

The Framework of Situated Learning

Lecturing, the most commonly used pedagogy in American universities [24], is based on an industrial model of assembly line factory production. Students move together along the prescribed trajectory of a spiral curriculum in hopes of exiting the production line with a high quality education fully prepared to transfer the abstract knowledge, skills and attitudes acquired during coursework to a wide variety of engineering careers and tasks. As demonstrated by a series of standardized and teacher-made tests, students are credentialed by degree conferral that they can begin a career as an engineer with the requisite information represented and stored in their memories. This approach rests on several key assumptions.

- Abstract knowledge is best, as it can apply to many concrete situations.
- Knowledge is represented and stored in memory and retrieved later on the job as needed.
- There is 1 instructional process, curricular sequence, that will work for all students.
- There are capital “T” Truths that can be objectively known and tested.
- Teaching is a matter of telling students the Truths and ensuring they can accurately recite and reproduce them in test situations.

Contemporary situated learning theories question and reject all these assumptions. The literature of Situated Learning suggests that knowledge is not abstract, but rather is indexical, tied to the context and situations in which it is experienced [8]. Knowledge from one class often remains indexed to that class, and knowledge from school is indexed more to school settings and getting an A, than it is to performing the duties of engineering in the context of getting paid to engineer things. From this perspective, knowledge is best demonstrated in authentic action (or at least simulated scenarios), and doing is an essential part of knowing. Since all knowledge is posited as situated, every learning experience is unique. In fact, it is taken as fundamental that no 2 students experience a lecture in the same way. So the assembly line concept does not apply well to classroom instruction, since as Heraclitus wrote, you can never step in the same river twice. Two students sitting in the same class do not receive identical instruction, professors do not provide the same content from semester to semester or even section to section, and even the same student re-viewing a recorded lecture will not learn the same thing from viewing to viewing. For this perspective, learning must be viewed as situated.

The philosophy of situated learning rejects the idea that there is objective Truth apart from the knower, and this philosophical difference is present in the broader field of objective vs subjective ethics as well. Without delving deeply into the philosophy and psychology of constructivism and situated cognition, for our current purpose it will suffice to say that small "t" truth is socially constructed and subject to change over time, as with the observer effect of quantum mechanics or the designation of Pluto as a planet. Ethics may apply differently in different situations, and be enacted by individuals differently at different times. This seems similar to the philosophical claim of ethical relativism, but rather than simply asserting there are never simply right/wrong answers to ethical conflicts of interest, our work draws on the situated nature of learning and thinking; that is, *situated cognition*. With this in mind, teaching is not a matter of telling students the Truth, but rather inviting them to enact their developing "truths" in the context of the community of engineering practice, with personal reflection and social feedback on their ability to act wisely in various realistic circumstances. This is an approach called "cognitive apprenticeship" in the situated cognition literature e.g., [25].

The framework of situated learning provides a different set of assumptions that guide our adoption of game mechanics for engineering ethics instruction:

- Situated knowledge is best, as it demonstrates current understanding in context.

- Knowledge is represented through interaction with the world, during university engineering coursework just as it is on the job, thus the more authentic the classroom work, the better.
- Each students' learning is unique and personal, drawing on their own unique experiential history.
- Truth (about ethical behavior) is socially defined and draws on humans' rational and emotional thoughts.
- Teaching is a matter of (cognitive) apprenticeship, leading students toward increasingly more central participation in the community of engineering practice.

Description of the Games

The collaboration between the universities has produced three games designed to promote ethical thinking and learning. These games are currently being tested by first year students at both universities.

The first game is called Cards Against Engineering Ethics (CAEE). This game uses the game mechanics of the popular card game Cards Against Humanity (a private LLC game company product) including similar rules for turn-taking and similar prompt and response cards [26]. One player is randomly chosen to be the judge and is given a prompt card to read aloud. The rest of the players are given a hand of response cards and need to pick the one that they think goes best with the prompt card. They will hand their chosen card over to the judge who will pick the best response card. The player whose card is chosen is the winner of the round. The rules to the game are quite similar to the original Cards Against Humanity. The game itself differs from its source concerning the card topics. The prompt cards are about ethical scenarios with many of them based on real life engineering disasters. For example, one prompt card references a bridge that collapsed in Genoa with the text "_____ led to the collapse of the Morandi Bridge in 2018", with the underscore being the blank where the response card would fill in. Students would then look at their hand of response cards to find one that could best fit. Response cards range from "Bribes and kickbacks" and "Cutting corners and rushing deadlines" to "Labeling a diagram incorrectly", "Politics", and "Aliens" . Students play multiple rounds of the game, with minimal instruction on how they should handle the winners. As the instructors, we do not tell them which cards, if any, are the right answers, we encourage them to use different criteria for choosing the winner with each round. This criteria can consist of response cards that are humorous, to cards that are most ethical/unethical in the given scenario. Each game should take around 20 minutes. Ideally, we hope that this game puts students in a playful space and allows them to choose humorous unethical responses in order to promote discussion. If a student finds the wrong answers funny, then that could help them understand why those answers are wrong.

The next game developed is Toxic Workplaces. In this game, players are given a scenario ending in an ethical dilemma. They are then asked what they would do to solve this problem and are given 4-7 cards describing possible responses. The game itself contains data from a first-year engineering student survey of those same ethical dilemmas. Each choice contains a secret percentage, how many first-year engineering students chose that option. It is up to the players to rearrange the options from most picked to least picked. In some ways this parallels the play of the TV game Family Feud in which players are asked to anticipate the top survey responses to a prompt. The players need to put themselves in first-year engineering students' shoes and try and imagine what they would prioritize. The players win if they can successfully organize the responses from most picked to least picked. One example scenario is based off of the NASA Challenger disaster. The scenario puts the player in the position of senior engineer working at the fictional company, Rings-R-Us. They are responsible for o-ring development for the next space shuttle. They also have a family to support. In the scenario, they find out that the o-ring failure rate is fairly substantial. They are advised by their superior to continue with the scheduled launch. The players are then given scenarios A through F, with each ranging in severity. Students can do nothing for the sake of their job, they can pass off responsibility to NASA, and they can go public and release sensitive data to stop the launch. Each response has a pick percentage based on first-year surveys and the players need to rearrange each card in the order they believe is highest. Afterwards, we ask the students to reflect amongst themselves with some questions. What strategies did they use to justify their ordering? Are these ethical scenarios similar to ones you experience in your everyday life? How might they be different? A full *Toxic Workplaces* game and reflection can take up to 75 minutes. The game is designed to prompt players to not only consider what they would do in an ethical scenario, but also have them imagine what other first year engineering students chose.

The third game developed by this collaboration is called Mars: An Ethical Expedition. This is a choose-your-own-adventure game meant to run over the course of a semester, with decisions made on a weekly basis, instead of one extended instance of game play. In this game, there are 12 chapters, each with their own ethical dilemmas. Players are asked to imagine a scenario in which they are engineers on a Martian colony when they find that their communication has been sabotaged. Will they be able to re-establish communication with the other colonies? Will the saboteur strike again? Each week, the players are presented with choices to make, and those choices impact the next week's narrative. The dilemmas can range from potential life or death adventures to more mundane scenarios. Should they let an infected individual into the colony? Do they choose to spend time comforting a co-worker instead of finding the saboteur? After each chapter, the players vote on the path before them and the option with a majority is chosen to progress the story. After each vote, the players are then asked some follow up questions pertaining to their choice. One example scenario consists of a skilled biologist refusing to do his job. He finds his particular assignment unethical. In the story, the class is the head commander of the colony, and needs to confront the individual. Should they order him to continue, have a less experienced biologist take over, or agree and not have the task done? Each student can vote on the three choices and the option with the most votes is picked to continue the story. Next class time, the story picks up from their last decision. Each scenario includes some follow-up questions to ask the student related to their decision. These can range from more personal statements such as "Do you enjoy working in a group?" to weighty ethical dilemmas such as "Is it okay to bring harm to a sentient being for the good of the colony?". This game will hopefully show players that ethical dilemmas show up in their everyday life and not just as these major life or death moments.

Conclusions and Ongoing Research

We are designing these 3 games in hopes of increasing the engagement of typical freshmen engineers, often in large lecture settings, by inviting them to consider their ethical behavior in the context of game play. Drawing from the framework of Situated Learning, our games are designed to establish learning environments that break the 3rd wall of the typical teacher-student roles. By providing students license to explore their ethical thinking in the context of playful responses and role playing, these assignments are designed to encourage students to think and act as they might on the job, rather than within the constraints of a graded university course. In addition the game mechanics enable them to explore even highly unethical responses and do so in a fun playful manner, which still enables reflection on those ethical choices. The intention is for students' interrogation of ethical engineering to be indexed to a more authentic and realistic context than is typical of a freshman engineering student under the watchful eyes of a lecturing professor. Our work to evaluate these games is ongoing and includes questions about typical moral reasoning measures (DIT2 and EERI) as well as the impact on the quality of student think-aloud reasoning, their conceptual development as indicated by concept maps, and their overall interest and engagement with game play as experienced as playful and thought provoking.

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