Investigating Game-Based Instruction as a Tool for Engineering Ethics Education in a First-Year Engineering Program

Joshua B. Reed
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INVESTIGATING GAME-BASED INSTRUCTION AS A TOOL FOR ENGINEERING ETHICS EDUCATION IN A FIRST YEAR ENGINEERING PROGRAM

by

Joshua Reed

A Thesis

Submitted to the
Department of Experiential Engineering Education
Henry M. Rowan College of Engineering
In partial fulfillment of the requirement
For the degree of
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at
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Abstract

Joshua B. Reed  
INVESTIGATING GAME-BASED INSTRUCTION AS A TOOL FOR ENGINEERING ETHICS EDUCATION IN A FIRST-YEAR ENGINEERING PROGRAM  
2021-2022  
Scott Striener, Ph.D.  
Master of Science in Engineering

Behaving ethically is a core foundation within engineering and is a necessity according to the National Society of Professional Engineers. Therefore, engineering ethics education has been increasingly encouraged within engineering curriculums in higher education. A trend toward more active learning strategies is being researched and utilized within the engineering ethics space. One strategy that has been growing in popularity in instruction is game-based learning or using educational games with instruction to accomplish learning goals. To this end, three games have been created by researchers that are designed to aid in the instruction of first-year engineering students around ethical decision making, reasoning, and awareness. This thesis study explores how first-year engineering students conceptualize engineering ethics prior to formal education and investigates how game-based instruction can be used as an effective, situated and playful learning strategy. Students were assessed on their ethical knowledge, ethical reasoning, and student attitude through concept map analysis, the Defining Issues Test 2 (DIT-2) the Engineering Ethical Reasoning Instrument (EERI), and survey responses. While there was little to no change in the learning outcomes of the students, it was found that the students were engaged and enjoyed the games. This study adds to the field of engineering ethics education and spreads the use of different active learning strategies that can be used to improve the quality of instruction.
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Chapter 1

Introduction

Background

In the last few decades there has been a large shift in engineering education, specifically in the area of engineering ethics. ABET EC 2000 added “understanding of professional and ethical responsibility” as one of the learning outcomes of university accreditation [1]. Following this addition, universities implemented many techniques and pedagogies that would help develop the ethical skills of engineering students. However, the subject of engineering ethics remained underdeveloped in many college and university curriculums. One study found that while there were components of the curriculum that focused on engineering ethics, instructors and faculty had difficulty establishing explicit goals and monitoring the learning outcomes of students and that it was common for faculty to be unaware of how they were supporting their students’ ethical and professional development [2]. Noticing this flaw, researchers in engineering education have set their sights on creating new and effective instruction for the area of engineering ethics.

Current engineering ethics teaching commonly uses methods such as case studies and lectures that focus on professional codes of ethics and rules, while others have found there to be more effective methods that rely on learning theories such as situated learning [1-6]. One instructional practice that is growing in popularity in many areas of education is game-based learning. This style of instruction utilizes games that are engaging and active to produce learning outcomes in students. Games have shown to be
affective in many areas of education and have even been implemented, albeit not often, in engineering ethics education [7][8][4]. Game-based learning is effective at both increasing learning outcomes in students as well as improving student attitudes and engagement [9]. This study aims to investigate the effectiveness of game-based learning methods as a useful tool in engineering ethics education. In addition, it will explore how first-year students conceptualize ethics before and after formal ethics education.

**Purpose of Study**

Engineering is not solely about the technical skills and knowledge that are the prominent focus in traditional engineering education. Major engineering projects in all disciplines require social and ethical examination on the part of the engineer. All engineering works have an impact on the society in which they are situated and therefore engineers are responsible for analyzing these impacts in social, behavioral, and ethical contexts as part of their job. There have been many major failures in which engineers have been criticized for their ignorance of societal impact or lapses in ethical judgement. One example of this is the Flint, Michigan Water Crisis, in which engineers did not study the societal impact of potential lead pipe corrosion and then did not uphold their ethical responsibility when addressing solutions [10]. In the face of this and many other social and ethical shortcomings of engineers, engineering programs have an obligation to effectively improve their curriculum to address these problems.

Engineering curricula should be designed to support improve student education in areas of ethics and social sciences within engineering. This will allow for students to start developing the non-technical skills that are often overshadowed by the more technical aspects of engineering. This early implementation of social and ethical
education may contribute to the appreciation and respect that these areas need in the engineering space, and hopefully lead to an increase in the production of engineers that uphold the ethical standards of the National Society of Professional Engineers.

This study is part of an NSF grant titled “E-ETHIC$^3$S: Engineering Ethics Through High-Impact Collaborative/Competitive Scenarios” that is studying engineering ethics education and the effect of game-based instruction. This three-year long study aims to both influence and measure the ethical awareness and reasoning of first-year engineering students through game-based instruction. Three games were created for use in this study, which students will play as part of an activity for class. The three games, Cards Against Engineering Ethics, Toxic Workplace, and Mars: An Ethical Expedition were all designed to be engaging and novel instructional strategies while also improving students’ ethical learning outcomes.

The study performed a baseline assessment of first year engineering students’ ethical reasoning using the Defining Issues Test 2 (DIT-2), Engineering Ethical Reasoning Instrument (EERI), and think aloud protocols. The games were then implemented in the engineering classroom for half of the students. The students were assessed again after the first year to investigate any changes between the two groups. This thesis is an extension of the grant that adds the use of concept maps as an assessment tool and focuses on how students conceptualize ethical decision making prior to formal education and if the game-based instruction has any effect.

**Study Design, Methods, and Outcomes**

This study focuses on these two main research questions:
1. How do first-year engineering students conceptualize ethics and ethical decision making prior to formal education in college?

2. Do the game-based learning tools work effectively as situated learning and playful learning strategies? If so, who do they affect and how?

The study is broken down into two phases based on the research questions. Figure 1 shows what is being assessed of the students on the left as well as the assessment methods. The arrows then show which research question the data are used to investigate on the right.

**Figure 1**

*Thesis Framework*
The first phase of the study uses data collected from over 1,000 first-year engineering students prior to any ethics education. The data collected was a mix of two different measurements, ethical reasoning and ethical knowledge. To assess ethical reasoning, students were asked to complete either the DIT-2 or the EERI which consist of ranking and rating items related to moral dilemmas and produce scores that measure moral reasoning. The students were then asked to complete concept maps of the topic “ethical decision making” and were scored through text analysis, traditional, and holistic methods to measure ethical knowledge [11][12]. This was done to understand the breadth, depth, and connectedness of students’ knowledge of engineering ethics before receiving instruction [11].

The second phase of the study was conducted to investigate the effectiveness of game-based instruction as situated and playful learning techniques in the area of engineering ethics. The students from the participating universities, University of Pittsburgh, University of Connecticut, and Rowan University were divided into two groups, one using traditional instructional methods, such as lectures and case studies, and one using the game-based techniques. A second round of DIT-2, EERI, and concept map data was then collected from students. The scores of students who responded both semesters were paired for analysis. These pre and post data were then compared to detect any difference in change of level of moral reasoning or ethical knowledge. Finally, a survey was administered to capture student attitudes towards the game-based instruction method. This survey asked students an assortment of questions about whether the games held their attention, if they felt the games were thought provoking, and what they learned from each game involved in the instruction. The survey was originally designed for
general feedback to improve the games but was added to this study to gauge student attitude.

**Broader Impact**

Engineering ethics has been an understudied area within the engineering education community. Seeing how many engineering failures have been due to improper ethical awareness, reasoning, and decision making, this should be improved in engineering curriculums [13][14][15]. This study can be used to improve engineering ethics education in many ways. It can give greater understanding into how first-year students approach ethics and ethical decision making prior to formal instruction in an engineering context. This will allow for instructors to acknowledge any common misconceptions that students may hold in the area as well as areas that must be focused on more in engineering ethics education. It can also spread awareness of new and engaging instruction methods for engineering ethics education such as game-based learning. These novel pedagogies may improve education and student engagement in many areas including engineering ethics. Finally, the three games used in this study can be disseminated to other universities in order to incorporate ethics education in an engaging and memorable way. This can help to instill an appreciation and sense of duty for ethics within the minds of future professional engineers.
Chapter 2

Thesis Literature Review

What is (Engineering) Ethics?

Ethics are the “standards of conduct that apply to everyone” or in other words, ethics define the difference between right and wrong [16]. The moral principles that people abide by help determine the ethical decisions that they make daily. Asking questions such as “what are the consequences?”, “how will this affect others?”, or “do the benefits outweigh the cost?”, allow people to assess situations and determine what action is best to take. These ethical situations can be any kind of decision from something small such as whether or not to tip a waiter to large decisions such as whistleblowing on a large company. Engineering is a field in which people are placed in many ethically fraught situations as part of their jobs. Engineers also have a wide effect on the community around them, thereby raising the stakes of these ethical decisions. For this reason, it is of paramount importance that engineers follow a clear set of moral principles to act safely and fairly in a career that presents workers with many ethical dilemmas.

Ethics are commonly split into three different sects: common ethics, personal ethics and professional ethics [17]. Common ethics are the agreed-upon set of rules that govern a group or culture. Personal ethics are those sets of rules that govern right and wrong for each individual, which often come from culture, religion, family, etc [17]. Engineering ethics are a set of professional ethics, or “those special morally permissible standards of conduct that, ideally, every member of a profession wants every other member to follow” [16, pg. 93]. These professional ethics can be found in codes of
ethics created by companies or governing bodies such as the National Society of Professional Engineers. Engineering ethics are different from everyday ethics because they are more focused on the field of engineering. Engineers do not always directly see the consequences of their work. For example, a sensor could be created that is used in an autonomous vehicle. Months later the sensor could fail and cause a crash, but the engineer of the sensor may not directly experience this consequence. Being removed from the time and space of the consequences can make it difficult to conceptualize and assess the ethical implications of their work as an engineer.

The National Society of Professional Engineers states, “the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare” [18]. They explicitly hold engineers to a high ethical standard and therefore ethical behavior and understanding are necessary qualities for a successful engineer to have. This is further solidified by the Accreditation Board for Engineering and Technology’s (ABET) current requirement for student outcomes, which states that students require “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts”. To create a learning outcome in the area of engineering ethics, there has to be a way of framing ethics to exemplify and assess this learning. One of the most common moral theories is Kohlberg’s Theory of Moral Development [19].
Kohlberg’s Theory of Moral Development

The assessment instruments used in this study are based on the theory of ethical and moral reasoning in the widely popular framework, Kohlberg’s Theory of Moral Development [20]. This framework is an excellent fit for the study as it is widely recognized and can be used to exemplify the change in moral development that often occurs in the collegiate years. Based on this theory is the Defining Issues Test 2 (DIT-2) which can be used to assess the moral reasoning, and change therein, of first-year engineering students. Kohlberg’s moral development theory breaks down the moral thought process into three different levels [19]. Pre-conventional is the earliest level in which a person makes decisions based on their own self-interest and the effects on themselves [19]. When proposed with an option of whether or not to steal, a person at the pre-conventional level may choose not to steal because they could be caught and punished. The next level is conventional reasoning, in which a person makes decisions based on the expectations placed upon them from a social order, such as family, friends, or community [19]. A person at the conventional reasoning level may choose not to steal because it is against the laws that everyone in the community must follow. Finally, the last level is the post-conventional level. This is where a person makes decisions based on moral values and principles that are defined outside of the authority of their social order [19]. This would be when a person develops their own morals and are not defined by the expectations set upon them by an authority or group. An individual at the post-conventional level may choose not to steal because they feel that stealing is dishonest and unfair and against the values by which they live. The Heinz dilemma is a case study that Kohlberg used to describe the stages of moral development [21].
“In Europe, a woman was near death from a very bad disease, a special kind of cancer. There was one drug that the doctors thought might save her. It was a form of radium that a druggist in the same town had recently discovered. The drug was expensive to make, but the druggist was charging ten times what the drug cost him to make. He paid $200 for the radium and charged $2,000 for a small dose of the drug. The sick woman’s husband, Heinz, went to everyone he knew to borrow the money, but he could get together only about $1,000, which was half of what it cost. He told the druggist that his wife was dying and asked him to sell it cheaper or let him pay later. But the druggist said, “No, I discovered the drug and I’m going to make money from it.” Heinz got desperate and broke into the man’s store to steal the drug for his wife.

Should the husband have done that? Was it right or wrong?” [21, pg. 12]

Kohlberg states that it is not whether the response is yes or no, but the reasoning behind the decision. Figure 2 shows how different responses to the Heinz dilemma could fit different stages of moral development.
Figure 2

Kohlberg's Stages of Moral Development (Adapted from Schmitt [22])

Stage 6
Universal Ethical Principles
(What if everybody did that?)
“Human life has supreme inherent value. I couldn’t live with myself if I let her die.”

Stage 5
Social Contract Orientation
(It’s the consensus of thoughtful men)
“Society has a right to insure its own survival. I couldn’t hold my head up in public if I let her die.”

Stage 4
Law and Order Orientation
(Do your duty)
“Saving a human life is more important than protecting property.”

Stage 3
Good Boy, Nice Girl Orientation
(Do it for me)
“He should do it because he loves his wife.”

Stage 2
Instrumental-Relativist Orientation
(If it feels good, do it)
“If his wife is nice and pretty, he should do it.”

Stage 1
Punishment and Obedience Orientation
(It’s OK to do it if you don’t get caught)
“It depends on who he knows on the police force.”
Rest added to Kohlberg’s theory and created the Neo-Kohlbergian theory of moral reasoning that showed a more adjustable framework in which there are transition phases between levels of moral reasoning [23]. Rest had three schemas which were comparable to Kohlberg’s levels of moral reasoning changing pre-conventional to personal interest, conventional to maintaining norms, and keeping post-conventional. Each schema is split into two types, one consolidated and the other transitional [24]. Consolidated means that there was predominantly one schema used whereas transitional has more equal use of multiple schemas [24]. The inclusion of the different types, consolidated and transitional, shows the complexity of moral reasoning and how people do not always reason based on one single stage of Kohlberg’s model of moral reasoning. Rest’s model digs deeper into how one approaches an ethical situation and was the basis for the creation of the Defining Issues Test that is widely accepted as an assessment of moral reasoning.

Why Engineering Ethics?

The National Society of Professional Engineers (NSPE) states that ethical awareness and reasoning are crucial to the creation of a successful engineer [18]. This large ethical responsibility comes from the fact that engineers have a direct impact on society [18]. There are many examples of failures that have been caused by lapses of ethical judgement in the engineering community. Popular failures such as the Volkswagen scandal [13], the Boeing 737 Max crashes [14], and the Florida International University bridge collapse [15] are often cited as examples of why engineering ethics is so important. These engineering failures are often discussed to exemplify the wide reach that engineering projects have, but the sentiment can often be lost in the repetitive use, or
the distance between the event and the student, or sometimes even the lack of visual evidence of the consequences [16]. But it is extremely important to understand the ramifications of these failures. For example, the VW scandal involved company leaders intentionally cheating emissions testing and allowing vehicles to release 40 times the maximum level of nitrogen oxides allowed by the U.S. Environmental Protection Agency [13]. This had 11 million vehicles illegally releasing air pollutants that cause respiratory problems across the world. While the consequences are difficult to see, it is important to understand the full weight of the decision that was made by the engineers responsible. The Boeing crashes and the FIU bridge collapse are much easier to see the horrible repercussions that were the effect of lapses in ethical judgement and safety regulations. The Boeing crashes resulted in the deaths of almost 350 people [14]. The FIU bridge collapse caused the deaths of six people and the injury of many more [15]. These were average people who were using the products and equipment that claimed to be safe and suitable for use. It is difficult to identify if any specific individuals are responsible for situations like this, but it is cases like this that show a pattern of unethical and unsafe work practices in the world of engineering. Whether it be falsifying data, using cheap equipment, or not meeting safety regulations, ethical failures can lead to incredible disasters and must be prevented. Failures due to poor ethical judgement are still happening and it is important to educate engineering students on ethics and nurture the growth of their ethical awareness and ethical reasoning skills. Through the education of future engineers, the pattern of unethical work practices can start to be corrected.

Since the 1980’s the Hastings Center, a think tank focused on ethics, has acknowledged that engineering students are often caught by surprise when faced with an
ethical situation in the professional world [25][16]. This group has been pushing for a focus on ethics education in engineering since then, and over the past few decades it has gained traction, with ABET requiring engineering ethics be taught as part of the engineering curriculum. The report, *The Engineer of 2020*, also specifies that engineers will need a framework upon which high ethical standards and professionalism can be built [26][27]. However, even with this push towards engineering ethics, studies have shown that there are still improvements to be made. One study found that professional engineers often wished to be better prepared for the ethical situations they face on the job [28]. Another study found that there was little growth in ethical decision making from first year to senior year with students and that they were often not prepared for ethical situations that they may encounter within the professional engineering workplace [29][30]. This shows that there are still improvements that can be made towards preparing engineering students for the ethical implications and situations of the professional work environment.

**Engineering Ethics Education**

There are many strategies that are used when tackling the challenge of implementing engineering ethics instruction into the curriculum. Three of the most common strategies for implementing ethics education are having a single course taught by professors outside of the engineering discipline, having a module-based approach with ethics instruction embedded into other courses, or a team-teaching style which utilizes both engineering and philosophy/ethics professors [5][1]. Academics debate the positives and negatives of these different teaching styles. Faculty has expressed an ease with presenting ethics as a stand-alone course with the expertise of an ethics professor.
However, some find that with the class being taught outside of the discipline, students may disassociate the class with professional engineering and undervalue what they are learning [31]. When looking at the cross-curriculum approach, some problems have been discussed with the difficulty of relying on instructors’ willingness to incorporate ethics into their course as well as a lack of depth and continuity through multiple different classes [1]. In general, best form of ethics instruction is a cross-curriculum model that embeds ethics within classes taken throughout the program, however, it is logistically difficult to implement for the faculty and staff [1][5][31][4][2].

Along with the placement of instruction within the curriculum there have also been different instruction methods discussed in research. Some of the most common pedagogies include case studies, focusing on codes of ethics, and focusing on ethical frameworks [5][1][4]. The instruction method that is found to be most effective is the use of case studies which has been shown to benefit students in many ways through exposure to ethical situations in an engineering context, allowing discussion between unique perspectives from different students, and comparing many different actionable responses that strengthen their ethical reasoning and ethical awareness [5][16][1]. However, it has been noted that case studies often deal with ethics in a very large scale such as disasters with clear-cut ethical violations and the average engineer would not face these types of situations often [32][33]. The use of codes of ethics and ethical frameworks have been compared and argued over, with some ethicists believing that ethical frameworks are the most important because they help strengthen ethical reasoning where codes rely on a theory that morality is defined by laws [1]. Although, there is an opposing view that codes of ethics help with students’ knowledge and comprehension, and help them
understand how ethics is contextualized in engineering and their role in society [1][5][34]. While developing ethical awareness and reasoning can be difficult in the engineering classroom, there has been a push towards the use of more active learning strategies including game-based instruction [35][7][33].

Over the past few decades there has been growing research into the area of engineering ethics in which it has been argued that improvements must be made [36]. Thus, there has been a shift toward new and innovative instruction in the area of engineering ethics [2][36]. These new instruction methods focus on active learning to diversify the learning theories used in engineering ethics education as well as meet the limitations of common methods such as case studies and lecture-based instruction [37][38]. Researchers and instructors have developed active learning strategies that expand on the case study pedagogy that is commonly used by having students research, reflect on, and present case studies in groups or having students create their own case study about engineering ethics [39]. Others have decided to combat the “black-and-white” view of ethics that is common in engineering education by holding debates on the ethics of ambiguous situations or having students roleplay more nuanced ethical situations [37][40]. Real life projects have also been used as a way to allow students to experience ethical situations in a real-world context that are then reflected on [2]. Alpay conducted a study in which students submitted activity proposals which were qualitatively coded to determine popular instruction strategies amongst students [40]. It was found that students most commonly proposed activities involving games, role playing, and debate [40]. Games have become increasingly popular in many areas of education and engineering ethics is no different with games being researched and
implemented, although not regularly [33][35][7][4]. These active learning strategies are still continuing to be developed and implemented to create a more well-rounded engineering ethics education experience.

**Game Based Learning**

Game-based learning has been an increasingly studied field in education in recent years. Gamification is a relatively new term that has been introduced to the education space and is the process of introducing game-like mechanics to activities that are not game-based, such as learning [41]. Some elements that are used in gamification are competition, playfulness, and cooperation; all which help to motivate students to have a desired behavior, in this case, learning [41][42]. Game-based learning has been shown to be effective in many areas of education such as motivation, student attitude, and learning outcomes, both overall and specifically within the engineering discipline [9][43][44][45]. Game-based instruction can also lead to learning through peer-to-peer discussion that commonly appears when using these strategies and cooperative learning strategies, such as a collaborative game, can have a positive effect on both student attitude and learning outcomes [46][47]. Games may also allow students to put themselves into an ethical situation by taking on a role of the subject and allows students to look at options that may commonly be overlooked or seen as unethical as it may be necessary in the context of the game. Affective skills such as communication between peers and collaboration within a team are also a large focus in game-based learning, giving an added benefit to the learning outcomes of the students. Skills such as these are seen as some of the most important skills in engineers, often more important than technical skills, and should be built upon in the classroom [47]. It has also been shown that the style of game, for
example, role playing, competitive, and collaborative and the game elements, such as complexity, realism, and narrative that are brought into the classroom have an effect on the students’ outcomes [48][49]. Another aspect that can have a positive effect on the likelihood of success in game-based instruction is the basis in established learning theories [49].

Over the past few years there have been attempts to introduce game-based instruction into the area of engineering ethics. Many of these attempts tend to be based in the role-playing realm in which students encounter ethical situations in an engineering context as if they were a character in the situation [4][39][50]. Another style of game that was used was the Delta Design in which players play as a design group creating a residence on a fictional planet known as Delta P [33]. This game has the students approach a situation in which their design results in a death and they must reflect on the ethics of their design. This style of ethics game is mostly used as a jumping off point for discussion within the group and was intended to improve the students’ sense of responsibility [33]. Finally, Lockheed Martin developed an ethics game that was used for their yearly ethics training and has been adapted for use in college and university classrooms [35][7]. This game would provide the players with situations and multiple-choice responses for how to handle the situation, each answer has a point value associated based on how appropriate the response is. Most of these studies do not assess the effectiveness of the games that they present, however, one does conduct a survey that shows an increase in engagement when using the ethics game [7].
**Situated Learning Theory**

This study examines how game-based learning can be implemented in the education of engineering ethics with first year university students. The game-based instruction used in this study was created on the basis of the situated learning theory, which shifts the focus from the cognitive processes that produce learning to the “social engagements that provide the proper context for learning to take place” [51, pg. 14]. A model of situated learning can be seen in Figure 3.
Some researchers argued that western curriculums have focused on theory within the classroom and lacked a more contextual learning experience [53]. If we understand that knowledge is situated within the context, then students would only contextualize ethics within the classroom. However, there has been a push towards more situated
learning pedagogy in the classroom recently through the study and creation of different instructional tools [54][55][6]. These strategies allow for instructors to simulate new contexts for students to apply their skills and work on developing ethical awareness and ethical reasoning. Situated learning has been found to improve learning outcomes and transitioning lessons to real world contexts [56]. Another key aspect of situated learning is the idea of being part of a community of practice [56]. This allows students to work with others in a collaborative way and learn from each other while practicing the skill in context. This translates well to the idea of game-based instruction that utilizes cooperative games, or games that involve players working together to accomplish a common objective. This removes the aspect of competition between players and allows for a focus on communication between players and teamwork. While instruction has a grasp on the social aspect of the situated learning process, it does not always give the opportunity to apply the lessons in context. With instructional practices such as game-based learning, these two aspects of social and context can be melded together.

Kolb’s Experiential Learning Cycle

Another learning theory that informs this research is Kolb’s experiential learning cycle. Kolb’s experiential learning cycle is split into four phases: experience, reflection, conceptualization, and experimentation [57]. This cycle would ideally play out with a student having an experience, then reflecting on the experience which will inform concepts and conclusions that will then be tested in future situations [57].
This theory can be well adapted to the research of game-based learning in engineering ethics education that is presented in this study. The students will have an experience with these games that simulate ethical scenarios, they will reflect on the experience through organized debrief, which will lead to their own conclusions on how to approach ethics in the engineering world, and finally test those conclusions when confronted with ethical situations in the real world.
Finally, Plass, Homer, and Kinzer (2015) discuss the theoretical background behind the design of educational games [58]. They discuss the cognitive, motivational, affective, and sociocultural foundations of game-based learning. The cognitive perspective has learners construct mental models by organizing what they observe from the game as visual and verbal representations in working memory and connecting them with prior knowledge [59]. From the motivational perspective, games can be used to engage and motivate students, and therefore foster learning, through elements such as story, competition, and aesthetic [58]. An affective perspective focuses on the player’s emotions, attitudes, and beliefs while playing the game and how those affects are related to learning [58]. Finally, the sociocultural perspective acknowledges that learning is socially constructed and focuses on how games can provide social engagement and contexts that improve learning [60]. Figure 5 shows how these different foundations inform the design of games to optimize the engagement and outcomes of students.
Figure 5

Playful Learning Model (Adapted from Plass [58])

Playful Learning

- Affective Engagement
- Cognitive Engagement
- Physical Engagement
- Social/Cultural Engagement

Learning Game Design Elements
- Knowledge/Skills
- Incentive System
- Learning Mechanics
- Assessment Mechanics
- Aesthetic Design
- Narrative
- Musical Score

Affect
- Motivation
- Interest
- Self-Efficacy

Cognitive
- Situated in Context
- Transfer of Learning
- Information

Social/Cultural
- Social Context
- Relatedness
- Social Interaction
Assessment

Assessing the learning outcomes of ethics curriculum has been notably very difficult for universities [61]. There are many forms of assessment in the area of engineering ethics such as examinations, ethical reasoning instruments, and interviews [4][62]. Two of the main areas that institutions hope to educate engineers in the area of ethics are ethical knowledge, or the knowledge of codes, procedures, and other ethical resources, and ethical reasoning, or the ability to approach an ethical situation appropriately and reason thoughtfully [62]. There is no single approach to assessing these areas of ethics education, but there are a wide number of accepted methods. Ethical reasoning has been assessed using interviews and essays that exemplify the student’s reasoning process when approaching an ethical situation [4]. This can be used in conjunction with a rubric to create a more standard assessment across a group. The Moral Foundations Questionnaire (MFQ) is another method of measuring the moral reasoning of students that is grounded in the moral foundations theory [63]. This questionnaire assesses the extent to which respondents prioritize the five domains of the moral foundations theory [63]. Another common assessment strategy for ethical reasoning is a moral reasoning instrument such as the Defining Issues Test 2 (DIT-2) or one of its discipline specific successors, the Engineering Ethical Reasoning Instrument (EERI) or the Engineering and Science Issues Test (ESIT) [24][61][64][4]. These surveys were developed with the intent of assessing the ethical or moral behavior of subjects by evaluating their responses to a series of ethical dilemmas [24]. The EERI and ESIT are more focused instruments because they narrow the scope of the ethical dilemmas to engineering and science-based context [64][61].
Ethical knowledge is generally easier to assess, as it is much more similar to other areas of knowing facts, such as codes of ethics or different ethical frameworks. The assessments of ethical knowledge are generally standardized examinations of ethical knowledge such as quizzes and test, like the ethics portion of The Fundamentals of Engineering Exam [62]. In this case, the Fundamentals of Engineering Exam is too advanced as it was created for students after a four-year degree and this study focusses on first-year students.

When assessing course or curriculum effectiveness, some researchers use course evaluations or student responses as a method for determining satisfaction [4]. These assessment methods are usually effective in investigating the attitudes of the students towards the instructional practices and whether they feel they have reached a desired learning outcome.

Many of the assessment methods for the effectiveness of engineering ethics curriculums were researched and debated when preparing for this study. Finally, it was decided that the best methods would be the DIT-2, EERI, concept maps, and student surveys. When judging the effectiveness of an ethics course in developing ethical reasoning, the DIT-2 has been shown to be a widely known and validated tool. However, it was also decided that a second moral reasoning instrument would be used that is more focused in the area of engineering. The EERI was chosen for this reason as well as contributing to the continuing validation of the survey. The EERI and DIT-2 produce many measurements, however, the P and N2 scores were used as the focus of this study. The P score quantifies the degree to which postconventional thinking is prevalent, whereas the N2 score is the degree to which postconventional thinking is present and
preconventional thinking is absent [64][23]. In terms of ethical knowledge, there were many common forms of assessment such as a standard exam, assignments, or reports that are graded, however, a more novel assessment was chosen. This study uses student-created concept maps to investigate the ethical knowledge and understanding that the students have. This is a method that has been shown to work in other areas but has not been utilized in the area of engineering ethics [65][12]. Finally, in assessing the student attitudes toward the ethics instruction, a survey was conducted for students undergoing the new instruction method.

The DIT-2 is a widely used and well validated test for assessing moral reasoning development. Previous research has been used to conduct studies into the effectiveness of ethics education for years. In 1985 it was found that ethics instruction as little as 3 weeks can make a meaningful difference in the moral reasoning of students [66]. A similar result was found in 1998 when Self and Ellison found ethical education intervention significantly increased the moral reasoning of students [67]. However, there have been studies that showed that there was no statistical change in moral reasoning whether in a module-based instruction or a full ethics class instruction [68][69]. The Center for the Study of Ethical Development has generated norms from their DIT-2 database that have been used to compare scores in past studies [70][71]. Past research that has used the DIT and DIT-2 have shown that there is a statistical difference between male and female students’ moral reasoning, specifically with the N2 measurement, in many academic and professional areas such as medicine, law, and engineering [72][73][74]. Although, in the study conducted by Self and Ellison, there was no difference found between male and female [67]. Unlike the DIT-2, the EERI has not
been used as frequently in previous studies. Some studies that have used both the DIT-2 and EERI have noticed a substantial difference between their scores when taken by the same group [71][75]. This difference is hypothesized to be due to how the EERI is situated within the field that the students are studying. Unlike the DIT-2, studies using the EERI have found that there was no statistically significant difference in P or N2 scores between male and female engineering students, although the female means were slightly higher [76]. That same study also used qualitative methods to showcase how different cultures and ethnic groups focus on different ethical theories and may lead to differing scores [76].

Concept maps are tools “for people of all ages and all domains of knowledge to express their understanding about a topic” [77, pg. 38]. They have been used in the past by instructors to both help in instruction as well as for assessment of their students in many areas of study [11]. Previous studies have utilized concept maps in the area of engineering education, such as engineering entrepreneurial mindset [65]. That study used concept maps to assess the knowledge and understanding of students by analyzing their concept maps through traditional and holistic scoring [65]. Similarly, this study used concept maps as a way of assessing the knowledge and understanding that a student has of engineering ethics. There are two main methods of scoring a concept map, traditional scoring and holistic scoring, are values depicting how well a subject understands a topic [11][12]. Traditional scores, which will be explained further in the methods, are calculated through the number of concepts, highest level of hierarchy, and number of crosslinks [11]. Previous researchers, Watson, Barrella, and Pelkey, developed a program that analyzes concept maps and calculates traditional scores digitally [78].
While concept maps have been used to assess knowledge in other areas of engineering such as engineering entrepreneurship and industrial engineering, it has not been utilized in the area of engineering ethics [65][12].

**Filling the Gap**

This study aims to fill gaps that have been identified in research in the areas of engineering ethics education specifically through the use of game-based learning. First, the study aims to gain an understanding for how first year engineering students conceptualize engineering ethics prior to formal education. This will be done using concept map assessment which has been utilized in other engineering spaces, but not specifically in engineering ethics. This will be able to give a different, and detailed perspective of student understanding in the area of engineering ethics. It can be used to gather insight into the level of ethical knowledge that first-year students have prior to formal education, as well as any misconceptions that students may have. Next, game-based instruction methods have been created that can aid in the engineering ethics education space. The study will then observe how the games perform within the classroom and the effects that they have on student outcomes and attitudes. The use of game-based learning is always expanding and pushing for further advancement and, within the area of engineering education, will be a great improvement in a subject that may be difficult to teach.
Chapter 3

Methods

Research Framework

This study was conducted at three different universities, the University of Pittsburgh, the University of Connecticut, and Rowan University. The data collection was split into two different parts, the pre data and the post data collected at the beginning and end of the 2020-2021 academic year. All students were asked to complete a concept map as part of an assignment in the class in which they received engineering ethics instruction. As part of the assignment, students were given instruction on how to create a concept map and then asked to create their own on the topic “ethical decision making”. The instructions on how to create a concept map can be found in Appendix A. The students were then split in half with some completing the Engineering Ethical Reasoning Instrument (EERI) and the others completing the Defining Issues Test-2 (DIT-2). The students were then split into groups with one group in each university receiving their normal engineering ethics instructions, while the other was administered three engineering ethics games in addition to their normal instruction. Following the year’s instruction, the students were then asked to complete another concept map assignment on the topic “ethical decision making”. They were also asked to complete the same ethical/moral reasoning assessment, the EERI or DIT-2, that they completed the previous semester. The students that received game-based instruction were then asked to complete a feedback survey about their thoughts on the games, specifically in their ability to teach engineering ethics and keep students engaged. The ethical reasoning and ethical knowledge assessments will investigate the effectiveness of the game-based instruction
on the cognitive level of the situated and playful learning theories, while the survey will investigate the affective level, as seen in Figure 6.

Figure 6

Research Framework

Instrumentation and Variables

Defining Issues Test 2 and Engineering Ethical Reasoning Instrument

The Defining Issues Test (DIT) is an instrument that assesses the moral schemas that are activated within a person when making ethical judgements. Prior to the Defining Issues Test (DIT) the moral reasoning assessment method was conducting and analyzing interviews. However, this method has been questioned due to the limitations of self-
reporting one’s own cognitive process [24]. Due to possible limitations and the length of
time that is necessary for interviews, a faster and more valid assessment was developed.
The DIT asks a subject to read a dilemma and rate and rank items based on their “moral
importance” [79]. When a subject comes upon an item that they feel makes sense and is
a part of their guiding schema, they rate and rank it highly. Whereas, if they find an item
irrelevant or a low priority, they will rate and rank it low, meaning they are not using the
connected schema. The DIT then outputs the schemas that are primarily used and these
are the schemas that, presumably, the subjects use when approaching decision making
outside of the testing scenario [79]. This measures the ethical reasoning of the students
and gain insight into the moral development that may occur within engineering ethics
instruction. The DIT has since been updated to the DIT-2 in order to update the
scenarios, add a new scoring metric, and further detect bogus data [24]. An example of a
DIT-2 question can be found in Appendix B.

The DIT-2 is comprised of five ethical dilemmas [24]:

1. “Famine – A father considers stealing food from a wealthy person
   for his starving family
2. Reporter – A newspaper reporter debates whether to report a
   negative story about a politician
3. School Board – A school board chair member must choose
   whether or not to hold a potentially destructive open meeting
4. Cancer – A doctor wrestles with the idea of administering a lethal
   amount of painkiller to a patient
5. Demonstration – College students demonstrate against U.S. foreign
   Policy”
The DIT has been validated in terms of seven criteria that have been cited in over 400 publications. The DIT has shown differentiation of various age and education groups, longitudinal gains, significant relationships with cognitive capacity measures, sensitivity to moral education intervention, being linked to many prosocial behaviors and desired decision making, being linked to political attitudes and political choices, and reliability [24]. The DIT-2 was tested using four criteria: discrimination of age and education groups, prediction of opinions on controversial public policy issues, high correlations between DIT-1 and DIT-2, and adequate internal reliability [24]. Another study that was testing the validity of the DIT-2 found results consistent with Rest (1999) showing that the DIT-2 has sensitivity to moral judgement changes that occur with education, internal consistency, and is related to political identity [80].

Though the DIT-2 is a valid and widely recognized assessment of ethical reasoning, it was apparent that there should be a more discipline specific reasoning instrument. The Engineering Ethical Reasoning Instrument (EERI) was created by Zoltowski, Buzzanell, and Oakes to fill this gap [81]. This instrument is modeled after the DIT-2 in its framework, using dilemmas and having respondents’ rate and rank items. An example of an EERI question can be found in Appendix C.

The EERI has eight scenarios that are more focused in the field of engineering [81]:

1. “Housing Quality
2. Soap Box Derby
3. International Aid
4. Flood Control
5. Nurse Schedule Software
6. Water Quality
Like the DIT-2 it asks students to rate and rank a set of items for each scenario. These ratings and rankings are then used to determine the respondents’ personal schema phase. The EERI, having been created relatively recently, has not been validated as much as the DIT-2, however, there has been ongoing factor analysis in this time that have shown promising results [82].

**Concept Maps**

Along with ethical reasoning, this study was constructed to measure the ethical knowledge of students going through different ethics instruction. Concept maps were found to be a useful tool for measuring the knowledge and understanding that students have on the topic of engineering ethics as well as the change in knowledge that occurs through instruction. The concept maps were measured in two ways, traditional and holistic, which score both quality and quantity [11][12]. This study took inspiration from concept map studies in other engineering fields and applied it to the field of engineering ethics to gain insight into the prior knowledge of ethics in engineering students as well as any misconceptions that may be held [65][12]. The students were given instruction on how to make a concept map and then asked to create one on the topic “ethical decision making”. They were then used to compare the effectiveness of instruction methods to show any change in learning outcomes.
Student Feedback/Reflection Survey

The last area that this study measured the quality of ethics instruction was student satisfaction. This was assessed through the use of a survey that asked students about their feelings towards the new instruction method that was implemented. The survey consisted of 18 questions, six for each game, Cards Against Engineering Ethics, Toxic Workplaces, and Mars: An Ethical Expedition, that were used for instruction. The survey used a mix of Likert scale and open-ended questions used to gauge student engagement, attitude, and feedback. The original purpose of the survey was for students to give feedback for the improvement of the games and therefore the questions unfortunately did not have any measures to limit bias from potentially leading questions. The survey questions used were:

Table 1

Questions Asked for Each Game

<table>
<thead>
<tr>
<th>Question</th>
<th>Response Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The game held my attention while I was playing it.</td>
<td>5 Point Likert</td>
</tr>
<tr>
<td>2. The game was thought-provoking.</td>
<td>5 Point Likert</td>
</tr>
<tr>
<td>3. When I was playing the game, I was prioritizing &quot;winning&quot; the game.</td>
<td>5 Point Likert</td>
</tr>
<tr>
<td>4. When I was playing the game, I was prioritizing making &quot;ethical&quot; choices.</td>
<td>5 Point Likert</td>
</tr>
<tr>
<td>5. Comments on what you learned by playing the game:</td>
<td>Open-ended</td>
</tr>
<tr>
<td>6. Suggestions on how to improve the game:</td>
<td>Open-ended</td>
</tr>
</tbody>
</table>
Variables

This study used three main measurements when organizing and analyzing the results: ethical reasoning, measured by the DIT-2 and EERI, ethical knowledge, measured by concept maps, and student feedback, measured through survey responses. The students were broken down into demographic variable groups such as institution, gender identity, racial identity, and instruction method. The survey results were also broken down by individual game that was played by students. The variables are broken down in Figure 7.

Figure 7

Variable Breakdown

**Independent Variables**
- Gender
- Race/Ethnicity
- Game vs No Game

**Dependent Variables**
- DIT-2 and EERI scores
- Holistic score
- Traditional Score
Sample

Defining Issues Test 2 (DIT-2)

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 data was further broken down by gender identity.

Table 2

Gender Identity Breakdown for each DIT-2 Test

<table>
<thead>
<tr>
<th>Gender</th>
<th>Pre (n = 440) (331 Pitt, 109 Rowan)</th>
<th>Post (n = 237) (198 Pitt, 39 Rowan)</th>
<th>Paired (n = 210) (174 Pitt, 36 Rowan)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Pitt</td>
<td>60.1%</td>
<td>39.9%</td>
<td>63.1%</td>
</tr>
<tr>
<td>Rowan</td>
<td>82.6%</td>
<td>17.4%</td>
<td>74.4%</td>
</tr>
</tbody>
</table>
Table 3

*Race/Ethnicity Breakdown for DIT-2*

<table>
<thead>
<tr>
<th>Race/Ethnicity</th>
<th>Paired (n = 210)</th>
</tr>
</thead>
<tbody>
<tr>
<td>African American or Black</td>
<td>3.3%</td>
</tr>
<tr>
<td>Asian or Pacific Islander</td>
<td>12.9%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>3.3%</td>
</tr>
<tr>
<td>American Indian/Other Native American</td>
<td>0%</td>
</tr>
<tr>
<td>Caucasian (Other than Hispanic)</td>
<td>76.7%</td>
</tr>
<tr>
<td>Other</td>
<td>1.4%</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>2.4%</td>
</tr>
</tbody>
</table>

*Engineering Ethical Reasoning Instrument*

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 data is further broken down by sex in Table 4.
Table 4

*Gender Identity Breakdown for each EERI Test*

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>UConn</td>
<td>64.0%</td>
<td>36.0%</td>
<td>60.9%</td>
<td>39.1%</td>
<td>57.3%</td>
<td>42.7%</td>
</tr>
<tr>
<td>Rowan</td>
<td>78.3%</td>
<td>21.7%</td>
<td>64.6%</td>
<td>35.4%</td>
<td>65.6%</td>
<td>34.4%</td>
</tr>
</tbody>
</table>

Table 5

*Race/Ethnicity Breakdown for EERI*

<table>
<thead>
<tr>
<th>Race/Ethnicity</th>
<th>Paired (n = 175)</th>
</tr>
</thead>
<tbody>
<tr>
<td>African American or Black</td>
<td>7.4%</td>
</tr>
<tr>
<td>Asian or Pacific Islander</td>
<td>18.3%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>10.3%</td>
</tr>
<tr>
<td>American Indian/Other Native American</td>
<td>0.6%</td>
</tr>
<tr>
<td>Caucasian (Other than Hispanic)</td>
<td>59.4%</td>
</tr>
<tr>
<td>Other</td>
<td>0%</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>4.0%</td>
</tr>
</tbody>
</table>
**Concept Maps**

The concept maps were implemented at the beginning and end of the academic year and were paired together for analysis. There was a total of 225 responses (37 Pitt, 62 Rowan, and 126 UConn) to the pretest. Pitt did not respond to the posttest, but there were still 232 responses (34 Rowan and 198 UConn) that were analyzed. While there were many concept maps collected in both semesters, only 50 students completed both a pre and post concept map (15 Rowan and 35 UConn). The posttest and paired groups can be further broken down between those who played games and those who did not. No demographic information was collected as part of the concept map assignment.

**Description of Games**

Three games were created and used in this study to aid in the instruction of engineering ethics: Cards Against Engineering Ethics, Toxic Workplaces, and Mars: An Ethical Expedition. The creations of these games have been ongoing projects from UConn and Rowan with the motivation of creating game-based, active learning instructional methods in the area of engineering ethics. Being based in learning theories, it is hoped that they are successful in creating cognitive, affective, and socio/cultural foundations for the students. On the cognitive level, it is hoped that the students reach the learning goals. On the affect level, it is hoped the students have positive attitudes towards instruction. And finally, the group play aspect of the games will put the students in a social learning setting that is necessary in these theories. Each game has a set of debrief questions paired with them that serve as reflections for the students to fully realize the learning outcomes intended through implementation.
Cards Against Engineering Ethics

Cards Against Engineering Ethics is a game that is similar to existing games such as Cards Against Humanity and Apples to Apples, but with the theme of engineering ethics. Each round a prompt is given that is related to engineering, such as “_____ led to the collapse of the Morandi Bridge in 2018”, where the blank space is filled in by response cards from each student playing. There are many response cards ranging from “Cutting corners” to “Politics” and even comedic responses such as “Adam West”.

Figure 8

Example Round of Cards Against Engineering Ethics

Once each student submits a response card, the player who drew the prompt reads all of the responses and chooses their favorite as the winner. The students are intended to play multiple rounds of the game and can identify both entertaining responses and ethical
responses. Following the game play, the students are asked to reflect on the cards that they saw being chosen for each prompt. They are then asked the list of debrief questions below:

Recall some of the more serious cards:

1. Why were these appropriate answers?
2. What does the chosen response say about the ethical principles the group was using?

Recall some of the funniest cards:

1. Why were/How come these choices were wrong?
2. What lines did they cross?
3. What are some lines that engineers shouldn’t cross?

This game provides a fun and engaging foray into the world of engineering ethics by giving students an opportunity to identify ethical and unethical responses in an interactive and sometimes humorous setting. Cards Against Engineering Ethics can start discussions that allow students to work on communicating ethical perspectives as well as improving ethical awareness.

*Toxic Workplaces*

Toxic Workplaces is a game that has students read a case study and a variety of different responses that the character in the case could choose to do. Each response was given as a survey to a group of first year engineering students and asked which response the students would choose if they were in the scenario. The players are then asked to rank the responses by the likelihood the responses would be chosen by their peers. One example is this case that is based on the Challenger disaster.
As a senior engineer with a spouse and 2 kids working at Rings-R-Us, you are responsible for project leadership and communication for the O-rings used in the NASA SpaceX Mission to Mars launch module. You are also responsible for keeping your family supported, saving for college, maintaining your home in a good neighborhood, and keeping up with your neighbors. Your brother is much less successful, and your aging parents will likely need your support in having a comfortable and healthy retirement.

Rings-R-Us is the sole source contractor for key components of the launch module. As such, they are given lucrative contracts without need for a competitive bidding process. This gives you, and your company, a comfortable stream of income on which to plan and grow. You have signed non-disclosure agreements (NDAs) to protect the results of your testing and the designs that make the sole source contracts possible.

Your company has done thorough testing of its O-ring product for the launch module. The data show the product is stable and highly reliable as long as the temperature stays above freezing. But bad things can happen once the temperature drops below freezing.
Your personal analysis, based on your company’s trials and data, shows that launching at 31°F would lead to substantial risk of failure, perhaps as bad as 13% failure rate.

Because NASA is both a scientific as well as political entity, they must consider how it looks when they have to scrap a mission and lose media coverage. Although it is January, NASA is convinced any cold weather should not be a factor big enough to cancel a launch. Using their own charts of data on 1 set of recent O-ring tests, they estimate a 0.001% fail rate, and also cite a 20-year-old US Air Force study of failure probability for other jet engines at 3-6%.

… What should you do?

This case has six responses:

Case Response 7.A
Do Nothing. To avoid unwanted liability and to ensure your own job security, the best thing you can do at this point is keep your mouth shut and hope for the best.

Case Response 7.B
Call your NASA administrative contact and lay it on them. Let them know you have advised them of the issue and any further consequences are their responsibility, not yours.

Case Response 7.C
Your responsibility ends with reporting your opinion to your NASA administrators. After that, you can speak up further if asked, but otherwise it will be best to protect yourself and your company by going along with decisions made at levels above your pay grade.

Case Response 7.D
Go Public. This is not something you should keep to yourself. Call the local reporters and see if they will pick up the story, and also report to your NASA administrators and company executives.

Case Response 7.E
Advocate strongly against the launch while remaining private, even making yourself an impasse to progress, and risking your own career. You need to do everything within your chain of command to ensure safety is maintained even if it adds delays and unwanted press.

Case Response 7.F
Secretly sabotage the rockets, causing millions of dollars’ worth of damage, ensuring that they won’t fly in time, but protecting the astronauts from a possible accident.

After the students have ranked the responses by their likelihood of being chosen by their peers, they score and end the game.

**Figure 9**

*Example Order for Toxic Workplaces Responses*

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>30%</td>
<td>10%</td>
<td>15%</td>
<td>45%</td>
<td>0%</td>
</tr>
</tbody>
</table>

*Note.* Green = correct, Red = incorrect

After the game, students are asked to re-organize the responses in order of how ethical they think the response is regardless of what their peers would choose. They are asked to identify any differences between the two rankings and reflect on why those differences occur. They are then asked this list of debrief questions:

1. Did this game change the way you think about ethics in the engineering workplace?
2. Reflect on the strategies you used while playing the game. (i.e. beneficial actions, detrimental actions, and what you would do
3. How did your experience and feelings differ from others in the group?

4. Reflect on an ethical dilemma that you have personally encountered in your life. How was your decision-making process similar to that of this game?

5. How would you have handled a professional situation/scenario that you may have heard or seen (i.e., from the media, class, or word of mouth).

6. How do the ethical theories relate to the responses in this activity?
   A. Perform a clustering exercise placing each theory that applies under each response. Check with other teams.

7. What changes would you make to this game, if any?

Toxic Workplaces allows for different students to discuss and debate the ethics involved in a real-life engineering situation. It opens the floor to different perspectives held by students that have different backgrounds and ideas. It improves students’ ability to recognize ethical situations, critically reason through different responses, and openly discuss ethics in an engineering context.

**Mars: An Ethical Expedition**

The last game that was created is Mars: An Ethical Expedition, which is a choose your own adventure game that tells the story of a manager of a Martian colony that faces many ethical situations. This interactive story has 12 chapters and is intended to be
played over a whole semester and can be played as an individual student or with the entire class participating together. Every week the character encounters an ethical dilemma, and the players must vote on what action they would like to take. An example of one of these weeks is below:

“Every so often, a supply caravan from the main colony crosses the canyon to deliver much needed resources. Now, the bridge has been down for some time, and we haven’t had any success in repairing it. If this goes on any longer, the supply caravan will come, and be totally ignorant of this whole situation. The bridge still stands, and it could even support the caravan’s load, but who knows for how long. The caravan could cross the bridge, or the bridge could collapse. We’re not sure what the outcome would be. We can’t send the word to warn them without sending some of our own engineers across. And, even if we send our own people across, the bridge could still collapse!”

Apparently, there’s no way of knowing whether the bridge will collapse under the caravan’s load. With the unstable bridge, the colony won’t be getting supplies delivered any time soon. An emergency rationing program will need to be set up immediately. Hopefully this doesn’t cause any unrest.

You try to get Roy to clarify the dilemma. If you do decide to send your own engineers out, not only will they know that it’s structurally unsound, but they too would be put at risk. Yet, if you decide to let the other
colonists cross the bridge, they will have no warning and be walking into unknown danger.

What will you do?

- Send your own engineers across
- Wait for the other colonists to come

This action then leads to outcomes that change the course of the story.

Figure 10

*Example Section of Flowchart of Mars: An Ethical Expedition*
Each week also has additional ethical questions that the players address and dig deeper into the ethical dilemma and why they chose their response. These are the supplementary for the example previously given:

When performing a difficult task, do you think it’s better if someone knows the risks, or if they are ignorant to those risks?

- Ignorant to the risks
- Know the risks

If you decide to send your own engineers across, but no one volunteers to go, is it fair for you, as the leader, to decide who will cross?

- Yes
- No

The game is supposed to simulate the players encountering realistic ethical situations with responses that show in game consequences. This game is designed for students to not only be able to identify real ethical situations in the engineering world, both macro and micro, but also allows for students to see direct consequences that choices can have on a situation. When played over the course of a whole semester, the students are required to continue thinking about ethics outside of the usual modules taught and shown that ethics are a consistent part of engineering.

Each game is designed using the principles of situated learning which state that quality learning happens due to social and contextualized learning. Each game allows to some degree for students to work with each other and share ethical perspectives as well.
as placing ethical situations in the context of engineering and simulating such scenarios. These games were created to both help with student engagement and attitude as well as learning outcomes. The games allow for a more contextualized view of ethics in the area of engineering and the ability for students to understand how to approach both micro and macro ethics as well as how to communicate with others about ethics. The hope is that the games allow for students to make connections between ethics and engineering as well as grow their skills in areas of ethical reasoning and ethical awareness. The debrief questions allow for instructors to create discussions around the games that furthers educational effectiveness through deeper discussion and reflection of what is being taught as well as drawing connections between the games and the lessons in the classroom.

Analytic Plan

The data collected for this study was used to investigate the two different research questions. The first research question exclusively used the data collected at the beginning of the academic year. The second research question compared the data from the beginning and the end of the year. The analytic plan is expressed in Figure 11 and explained in more detail in this section.
**Research Question 1: How Do First-Year Engineering Students Conceptualize Ethics and Ethical Decision Making Prior to Formal Education in College?**

The first part of the study investigates how first year students understand and conceptualize engineering ethics prior to instruction in college, therefore, only the pre data was analyzed. The concept maps were analyzed in three different but complementary ways: traditional scoring, holistic scoring, and text analysis [12][11]. Traditional scoring gives a concept map point values for the number of concepts, number of hierarchies, the number of levels the highest hierarchy has, and the number of crosslinks [11]. These components are identified in Figure 12. These values give insight into the breadth, depth, and connectedness of understanding that the concept map creator has. The number of concepts gives insight into the breadth of knowledge, the level of...
hierarchy shows the depth of knowledge, and the number of crosslinks exemplifies the connectedness of knowledge.

**Figure 12**

*Breakdown of Concept Maps (Adapted from Watson [11]*)

![Diagram showing the breakdown of concept maps with hierarchies and crosslinks.]

**Equation 1:** Traditional Scoring [11]

\[
\text{Total} = (\text{NC} - \text{NCL}) + (\text{HH}) \times 5 + (\text{NCL}) \times 10
\]

NC = Number of concepts, NCL = Number of crosslinks, HH = Highest level of hierarchy
The concept maps were then analyzed using the holistic scoring method which uses a rubric to score a concept map based on comprehension, correctness, and organization [12]. The holistic scoring process started with all graders receiving instructions on how to grade using the rubric with an example (Figure 13). All of the graders were then asked to score the same 5% of the concept maps and share their scores. The intraclass correlation coefficient (ICC) was found to determine reliability. When the reliability was strong enough, the maps were scored with any discrepancies being discussed amongst the group and settling what the final score should be. The graders were then each given equal shares of the next 45% of the concept maps to grade separately. The graders were then all given another 5% to score, share, and, when reliability was high enough, scores were settled on. The rest of the concept maps were divided equally amongst the graders and scored. This type of scoring addresses the limitation of traditional scoring by scoring based on content of concepts rather than just counting the components. Finally, the concept maps’ text was analyzed. The concept maps were converted into an outline of just the text and the frequencies of each word used were found. The percentage of concept maps that used each word was then found. This helped to investigate the content of the concept maps and the specifics of how students understand engineering ethics. These three techniques for analyzing the concept maps work well together as they all look at different areas. Traditional scoring is a perfect way to start parsing through the concept maps looking at the components that make up the concept map. Holistic scoring picks up where the traditional scoring is lacking by looking into the content of the concept maps. Finally, the text analysis gives
specifics into the most common concepts that students use in their concept maps.
Together they paint an extensive picture of how students understand engineering ethics.

Figure 13

*Holistic Scoring Rubric [12]*

<table>
<thead>
<tr>
<th>Comprehensiveness – covering completely/broadly</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>The map lacks subject definition; the knowledge is very simple and/or limited. Limited breadth of concepts (i.e., minimal coverage of coursework, little or no mention of employment, and/or lifelong learning). The map barely covers some of the qualities of the subject area.</td>
<td>The map has adequate subject definition but knowledge is limited in some areas (i.e., much of the coursework is mentioned but one or two of the main aspects are missing). Map suggests a somewhat narrow understanding of the subject matter.</td>
<td>The map completely defines the subject area. The content lacks no more than one extension area (i.e., most of the relevant extension areas including lifelong learning, employment, people, etc. are mentioned).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organization – to arrange by systematic planning and united effort</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>The map is arranged with concepts only linearly connected. There are few (or no) connections within/between the branches. Concepts are not well integrated.</td>
<td>The map has adequate organization with some within/between branch connections. Some, but not complete, integration of branches is apparent. A few feedback loops may exist.</td>
<td>The map is well organized with concept integration and the use of feedback loops. Sophisticated branch structure and connectivity.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Correctness - conforming to or agreeing with fact, logic, or known truth</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>The map is naïve and contains misconceptions about the subject area; inappropriate words or terms are used. The map documents an inaccurate understanding of certain subject matter.</td>
<td>The map has few subject matter inaccuracies; most links are correct. There may be a few spelling and grammatical errors.</td>
<td>The map integrates concepts properly and reflects an accurate understanding of subject matter meaning little or no misconceptions, spelling/grammatical errors.</td>
<td></td>
</tr>
</tbody>
</table>

While the concept maps investigate the students’ prior knowledge of ethics, the EERI and DIT-2 assess the students’ ethical or moral reasoning. The EERI and DIT-2 responses were scored and the P and N2 scores were identified. The P score quantifies the degree to which postconventional thinking is prevalent, whereas the N2 score is the
degree to which postconventional thinking is present and preconventional thinking is absent [64][23]. Once all of this data was analyzed individually, the EERI and DIT-2 scores were compared to previous studies of first-year engineering students.

**Research Question 2: Do the Game-Based Learning Tools Work Effectively as Situated Learning and Playful Learning Strategies? If so, Who Do They Affect and How?**

The second half of this study investigated the impact of game-based learning on the students as situated and playful learning strategies in the instruction of engineering ethics. This was done through comparing the scores, concept maps and moral reasoning instruments, of students before and after ethics instruction with groups split between those playing games and those not playing games as part of their engineering ethics instruction. This investigates the cognitive foundation that the situated and playful learning strategies aim to provide. The differences between the scores were compared between those groups in order to identify any affect the games may have had on learning outcomes in both the areas of ethical knowledge and ethical or moral reasoning. Paired T-Tests were conducted to compare these measurements and investigate the effectiveness of the game-based instruction. The demographic variables were also investigated to determine if there were any interesting differences between groups. This was done using a combination of multiple regression and t-test analysis. The game feedback survey was then used to gain insight into the student perception of the games and gauge student attitude and engagement with the games. This focuses on the affect foundation that is discussed as part of the situated and playful learning theories. The Likert scale data was analyzed to gain a general understanding of student attitudes toward the games, while the open-ended questions were used to find specific themes that students brought up. The
open-ended questions were specifically designed to draw out themes on what the games were effective in teaching the students as well as how the games can be improved.

**Organization of Results**

The results of this thesis will be separated into two sections by research question. The first investigates how first-year engineering students comprehend engineering ethics prior to formal instruction. This section will be further broken down by assessment method, starting with ethical knowledge and moving into ethical reasoning. The section will investigate ethical knowledge through the reporting of concept map traditional, holistic, and text analysis results. This will be followed by the investigation of ethical reasoning through the DIT-2 and EERI moral reasoning instrument scores.

The second research question investigates the effectiveness of game-based instruction as a situated and playful learning technique in the area of engineering ethics. This will be broken down into three different groups based on assessment methods: ethical knowledge, ethical reasoning, and student attitudes. The ethical knowledge will focus on the differences between pre and post concept maps split between the group that played games and those that did not. This will look at all the same measurements as before: traditional, holistic, and text analysis. Similarly, the effectiveness of the games will be investigated through the lens of ethical reasoning using the moral reasoning instruments DIT-2 and EERI comparing the differences between pre and post comparing the group that played games to the one that did not. Finally, the student attitudes of those who were instructed with the game-based methods will be reported and both the Likert scale and open-ended questions will be analyzed. Any interesting relationships between the demographic variables will also be reported in this section.
Chapter 4

Results and Discussion

RQ1: How Do First-Year Engineering Students Conceptualize Ethics and Ethical Decision Making Prior to Formal Education in College?

Concept Map Scoring

The concept maps that the first-year engineering students created before ethics education were scored both through the process of traditional scoring and holistic scoring. Traditional scoring was accomplished using the CmapParse program and the scores were then compiled in SPSS Statistics [78]. Traditional scoring found the number of concepts, number of hierarchies, highest level of hierarchy, number of crosslinks, and the total traditional score using the previously described variables.

Table 6

Descriptive Statistics for Concept Map Traditional Analysis (n = 225)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Concepts</td>
<td>16.30</td>
<td>7.25</td>
<td>3</td>
<td>45</td>
</tr>
<tr>
<td>Number of Hierarchies</td>
<td>5.34</td>
<td>3.67</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Highest Hierarchy</td>
<td>3.38</td>
<td>1.74</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Number of Crosslinks</td>
<td>1.77</td>
<td>3.50</td>
<td>0</td>
<td>28</td>
</tr>
<tr>
<td>Traditional Score</td>
<td>49.15</td>
<td>39.40</td>
<td>8</td>
<td>304</td>
</tr>
</tbody>
</table>

*Note. SD = Standard Deviation*
The descriptive statistics in Table 6 show that the average traditional score is about 49 points, but with a standard deviation of 39.4 there is large variation between students. A histogram of the total traditional score, as seen in Figure 14, is skewed right with a large number of students who approach ethics at a beginner level.

Figure 14

*Histogram of Traditional Score (n = 225)*

Breaking down the concept maps further and looking at the individual variables, an interesting trend can be found. The students focus more on the concepts known, but rarely show how those concepts are interrelated to each other with crosslinks. Conceptual knowledge is not just concepts, but specifically the connections between the
concepts [83][84]. Crosslinks are the weakest area of the concept maps with 68.9% having less than 2 crosslinks and an average of 1.77.

The holistic scoring statistics also give insight into first-year students. As seen in Figure 15, the comprehension and organization of the concept maps are substandard. The low organization scores again exemplify the lack of crosslinks that show the interrelation of concepts. The low comprehension scores show that the students have a beginner’s understanding of ethics prior to formal education. While the correctness scores were higher than the others, there were still room for improvement. The table of the descriptive statistics can be found in Appendix D.

Figure 15

*Means of Holistic Score Categories (n = 225)*

*Note.* Error bars are standard deviation
Breaking up the concept maps further into groups of the highest and lowest traditional scoring maps collected in this study adds more to this story. The two groups are made up of the top and bottom 25% of traditional scoring maps. This exemplified the differences in the components between the highest and lowest scoring maps. Looking at examples of a low traditional scoring map and a high scoring map in Figure 16, it is easy to see many of the differences between these groups. High scoring maps have more concepts and a denser looking map, as well as more hierarchies that go to deeper levels. Another interesting difference is the number of crosslinks, with higher scoring maps having more connections between concepts, showing a deeper understanding of the topic.
Figure 16

*Example of Low Vs. High Scoring Maps*

*Note.* Low Scoring Map on left (9 points), High Scoring Map on right (110).
The statistics of the split, in Table 7, show a more accurate picture of how the average low scoring map compares to the average high scoring map. The coefficient of variation (CV) is the ratio of the standard deviation to the mean and was used to more easily compare the dispersion of data between the different variables. The high scoring maps had twice as many concepts and maintained the variation. There is almost no difference in the number of hierarchies, however, the higher scoring maps show much deeper knowledge with over twice as many levels of hierarchy. The total scores are vastly different, with the higher scoring maps being almost five times higher, but the variation is almost double, due to a small number of very high scores. Finally, one of the most important aspects that can be seen is that the low scoring maps did not include a single cross link. This further validates that students need to learn how the concepts in this area relate to one another. Overall, the low scoring maps were more consistent in their map construction with lower variation, but high scoring maps had higher scores across the board.
Table 7

Descriptive Statistics for High vs Low Traditional Scoring Concept Maps

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low Traditional Scoring (n = 64)</th>
<th>High Traditional Scoring (n = 64)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Number of Concepts</td>
<td>10.14</td>
<td>3.29</td>
</tr>
<tr>
<td>Number of Hierarchies</td>
<td>5.08</td>
<td>2.70</td>
</tr>
<tr>
<td>Highest Hierarchy</td>
<td>1.98</td>
<td>0.49</td>
</tr>
<tr>
<td>Number of Crosslinks</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Traditional Score</td>
<td>20.06</td>
<td>4.40</td>
</tr>
</tbody>
</table>

Note. SD = Standard Deviation, CV = Coefficient of Variation

These scores start to paint a picture for how first-year students approach ethics and ethical decision making. While they may understand many concepts associated with ethics, they may not fully comprehend the relationships between these concepts. This showcases the need for instructors to focus on the interrelation of topics in the engineering ethics classroom which can lead to a deeper understanding of ethics and ethical reasoning [85]. Case studies and similar strategies, such as role-playing games based in case studies, have been shown to reinforce connections in many topics in engineering ethics such as analyzing situations, considering outcomes, acknowledging biases and values, implementing codes of ethics, and promoting an ethic of care [86][4].

Concept Map Text Analysis

Text analysis of the concept maps digs deeper into the specific concepts and words that the students bring up in their concept maps. The word cloud in Figure 17
represents many of the frequently used words and themes that were included in the students’ concept maps.

**Figure 17**

*Word Cloud of Common Concepts*

Tables 8 and 9 show the ten most frequently used words and the percentage of students that included them followed by a split between high and low traditional scoring maps.
Table 8

Text Analysis of Concept Maps (n = 225)

<table>
<thead>
<tr>
<th>Concept</th>
<th>% of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moral(s)</td>
<td>45.8</td>
</tr>
<tr>
<td>Right</td>
<td>34.2</td>
</tr>
<tr>
<td>Others</td>
<td>28</td>
</tr>
<tr>
<td>Wrong</td>
<td>27.6</td>
</tr>
<tr>
<td>Values</td>
<td>26.7</td>
</tr>
<tr>
<td>Personal</td>
<td>22.7</td>
</tr>
<tr>
<td>Good</td>
<td>22.7</td>
</tr>
<tr>
<td>Work</td>
<td>22.2</td>
</tr>
<tr>
<td>Problem</td>
<td>21.3</td>
</tr>
<tr>
<td>Consequence(s)</td>
<td>18.7</td>
</tr>
</tbody>
</table>
### Table 9

**Text Analysis of High Scoring vs Low Scoring Concept Maps**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Low Traditional Score (n=64) % of students</th>
<th>High Traditional Score (n=64) % of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moral(s)</td>
<td>42.2</td>
<td>48.4</td>
</tr>
<tr>
<td>Right</td>
<td>31.3</td>
<td>40.6</td>
</tr>
<tr>
<td>Others</td>
<td>28.2</td>
<td>Wrong</td>
</tr>
<tr>
<td>People</td>
<td>25</td>
<td>Values</td>
</tr>
<tr>
<td>Values</td>
<td>21.9</td>
<td>People</td>
</tr>
<tr>
<td>Wrong</td>
<td>21.9</td>
<td>Personal</td>
</tr>
<tr>
<td><strong>Consider</strong></td>
<td>20.3</td>
<td><strong>Good</strong></td>
</tr>
<tr>
<td><strong>Problem</strong></td>
<td>20.3</td>
<td>Others</td>
</tr>
<tr>
<td>Personal</td>
<td>18.8</td>
<td><strong>Consequence(s)</strong></td>
</tr>
<tr>
<td><strong>Respect</strong></td>
<td>18.8</td>
<td><strong>Law(s)</strong></td>
</tr>
</tbody>
</table>

*Note. Highlights show concepts that differ from each group.*

Understanding the prior knowledge of students is a pivotal part of the teaching process for the instructor [85]. The two main reasons to assess prior knowledge are to understand what students already know and what they may misunderstand. Assessing what students already know allows an instructor to tailor their course and more efficiently teach their students. Understanding any misconceptions that students may hold is also important so that instructors can remedy them before they cause more misunderstandings in the future. Prior knowledge is the foundation of understanding and misconceptions create a faulty foundation. Ethical awareness and ethical decision making are two of the most prominent learning goals in engineering ethics, but students often do not have a
complete understanding of the concepts and processes that are required for ethical
decision making [4][86]. The text data in Tables 8 and 9 start to understand the prior
knowledge that students have towards the learning goals in first year engineering ethics.

When looking at all of the concept maps, many of the students have a basis in
understanding the core principles of ethics and ethical decision making with a large
percentage using concepts such as “moral”, “right”, and “wrong”. The terms “others”
and “consequences” touches on how students understand that the characters of an ethical
situation play a role in the decision-making process. These terms also speak to students
coming into first year instruction with a consequentialist view of ethical decision making;
focusing on who it will affect and how. This type of decision-making framework is not
surprising as it falls in line well with the engineering mindset. Finally, “personal” and
“values” show somewhat of an understanding of the relativity of ethics. That each person
has their own view of an ethical situation and that everyone has their own perspectives
and values. These concepts also focus on “personal ethics” as opposed to “professional
ethics”. “Personal ethics” refers to ethics that a person identifies with in respect to people
and everyday situations, whereas “professional ethics” refer to ethics a person must
adhere to in their professional lives. Due to students not having as much work experience
in the professional engineering field, if any, it would be understandable that they would
focus primarily on “personal ethics” over “professional ethics”. Not only is this
information helpful for instructors to create a baseline of knowledge, but it is also
important to notice concepts that are not frequently recognized by students, such as
“codes of ethics” or “ethical frameworks”. These concepts are widely recognized as the
most important in the area of ethics and should be focused on in the classroom [3].
Seven metacognitive strategies that a qualitative study found to be used in ethical decision making are: “(1) recognizing the complexities of one’s circumstances, (2) seeking outside help, (3) questioning one’s own and other people’s judgment, (4) dealing with emotions, (5) anticipating the consequences of actions, (6) looking within by assessing personal motivations, and (7) considering others’ perspectives” [87]. The concepts that were identified in the concept maps to correspond to some of these strategies, for instance, looking at the consequences and assessing your personal values. However, there is plenty of room for improvement in this area. When looking at this study there are five more metacognitive strategies to be understood by the students. Opening up the discussion further shows that there are many avenues that students can take when approaching ethical decisions that are not frequently mentioned in these concept map responses, such as codes of ethics and ethical frameworks [3].

The differences between the concepts used by the top and bottom 25% of traditional scored concept maps were also analyzed. 7 out of the top 10 concepts used by each group were the same, which shows that there is a somewhat consistent understanding between the students regardless of their traditional scores. It is however important to note that the percentage of students who included the concepts were consistently higher for the higher scoring group. Looking at the differences in the top 10 concepts, it is seen that the higher scoring group focus on the surrounding elements of an ethical decision such as “consequences” and “laws” whereas the lower scoring group used more basic concepts about the act of decision-making such as “problem” and “consider”. This suggests that the higher scoring students have a deeper understanding of
the processes that are involved in ethical decision making such as considering outcomes and identifying rules and laws that govern a situation [87].

**Assessment of Ethical Reasoning Using the EERI and DIT-2**

The EERI and DIT-2 were both used to assess the students’ ethical reasoning. The mean of the DIT-2 P and N2 scores are compared to the DIT-2 norms of first-year students in Table 10. These norms were generated by the University of Alabama’s Center for the Study of Ethical Development. They collected responses from 652 diverse data sets from 2005 to 2009 that contain students from many different majors, disciplines, and areas of study [70]. The student scores from this study were statistically greater than the DIT-2 norms for first-year students scores [70]. The EERI statistics are also compared to a previous study of first year engineering students in Table 11 [71]. Like with the DIT-2, both the P and N2 student scores of the EERI are slightly larger but generally consistent with a previous study of first year engineering students.
Figure 18

*Clustered Bar Chart Comparing Student Mean Scores to Previous Studies’*

Means [70][71]

![Clustered Bar Chart](image)

Table 10

*DIT-2 Scores Compared to Norms [70]*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Student Scores (n = 440)</th>
<th>DIT-2 Norms (n = 10,319)</th>
<th>T-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>P</td>
<td>36.62</td>
<td>14.82</td>
<td>34.11</td>
</tr>
<tr>
<td>N2</td>
<td>35.29</td>
<td>14.03</td>
<td>33.42</td>
</tr>
</tbody>
</table>

*Note. SD = Standard Deviation*
Table 11

*EERI Scores Compared to Previous Study [71]*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Student Scores (n = 425)</th>
<th>Previous Study (n = 34)</th>
<th>T-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>P</td>
<td>57.50</td>
<td>18.00</td>
<td>56.56</td>
</tr>
<tr>
<td>N2</td>
<td>54.71</td>
<td>18.32</td>
<td>54.32</td>
</tr>
</tbody>
</table>

*Note.* SD = Standard Deviation

The EERI and DIT-2 scores were then split into groups of male and female. The male and female groups are compared in Tables 12 and 13. The females scored significantly higher on both the P and N2 scores for the DIT-2 which is in line with previous research [72][73][74]. The females scored significantly higher on both the P and N2 scores for the EERI as well, but with a lower effect size.
Figure 19

Clustered Bar Chart Comparing Male and Female Moral Reasoning Scores

Table 12

DIT-2 Male Scores Compared to Female Scores

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n = 289)</th>
<th>Female (n = 151)</th>
<th>T-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>P</td>
<td>33.90</td>
<td>14.26</td>
<td>41.84</td>
</tr>
<tr>
<td>N2</td>
<td>32.54</td>
<td>13.72</td>
<td>40.56</td>
</tr>
</tbody>
</table>

Note. SD = Standard Deviation
Table 13

*EERI Male Scores Compared to Female Scores*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>55.49</td>
<td>18.02</td>
<td>61.55</td>
<td>17.33</td>
<td>0.00</td>
<td>.341</td>
</tr>
<tr>
<td>N2</td>
<td>52.52</td>
<td>19.07</td>
<td>59.11</td>
<td>15.88</td>
<td>0.00</td>
<td>.365</td>
</tr>
</tbody>
</table>

*Note. SD = Standard Deviation*

The results of the EERI and DIT-2 suggest that engineering students come in with a standard level of ethical reasoning. However, they do not have a fully comprehensive understanding of the ethical knowledge that is required in the professional engineering world. It was also seen that first-year students do not fully understand the relationships between many of the concepts that they do know in ethics. This difference between moral reasoning and ethical knowledge may come from students leaning more on common ethics or personal ethics rather than professional ethics. As discussed, common ethics are the generally agreed upon set of rules in a society and personal ethics are the rules that each individual holds [17]. These are often instilled within people from a young age by the people and culture surrounding them [17]. Professional ethics are the agreed upon standards that guide those who work in a specific field [16]. It could be seen that these students understand how to react to a situation in engineering by applying common and personal ethics. This is not unusual because professional codes are often based on applying common ethics and laws to specific areas of a profession but holding the people within to a higher standard [88]. However, when students are asked to express
their knowledge on ethics specifically within engineering and the concepts that guide them, they lack a complete understanding. If this ethical knowledge is successfully introduced to the students, their comprehension of professional ethics within engineering may be greatly improved. Growing this relationship between common/personal ethics and professional ethics is something that engineering education curriculums should be striving for when producing professional engineers that live up to the standards set by the NSPE.

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 [72][73][74]. In previous research using the EERI, females scored consistently higher than men, but this difference was not statistically significant [76]. However, this study found that females scored significantly higher on both the P and N2 measures for the EERI. There has not been much research using the EERI and this difference will be interesting to continue studying as research with this assessment continues.

**RQ2: Do the Game-Based Learning Tools Work Effectively as Situated Learning and Playful Learning Strategies? If so, Who Do They Affect and How?**

**Concept Maps Pre vs Post**

The paired t-test for the scores of the concept maps from the section that played games shows that there was a significant increase in the traditional scores number of concepts, highest level of hierarchy, and total traditional scores. However, the holistic scores correctness, organization, and total holistic score all decrease from pre to post.
### Table 14

**Concept Map Paired Sample T-Test for Section with Games**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Post – Pre (n = 40)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>p-val</td>
<td>cohen’s d</td>
<td></td>
</tr>
<tr>
<td>Number of Concepts</td>
<td>3.43</td>
<td>5.21</td>
<td>0.00</td>
<td>0.657</td>
<td></td>
</tr>
<tr>
<td>Number of Hierarchies</td>
<td>0.00</td>
<td>2.00</td>
<td>1.00</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Highest Hierarchy</td>
<td>0.73</td>
<td>1.52</td>
<td>0.00</td>
<td>0.477</td>
<td></td>
</tr>
<tr>
<td>Number of Crosslinks</td>
<td>0.45</td>
<td>2.43</td>
<td>0.25</td>
<td>0.185</td>
<td></td>
</tr>
<tr>
<td>Traditional Score</td>
<td>11.10</td>
<td>27.92</td>
<td>0.02</td>
<td>0.398</td>
<td></td>
</tr>
<tr>
<td>Comprehension</td>
<td>-0.10</td>
<td>0.59</td>
<td>0.29</td>
<td>-0.169</td>
<td></td>
</tr>
<tr>
<td>Correctness</td>
<td>-0.28</td>
<td>0.77</td>
<td>0.03</td>
<td>-0.358</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>-0.34</td>
<td>0.65</td>
<td>0.00</td>
<td>-0.516</td>
<td></td>
</tr>
<tr>
<td>Total Holistic</td>
<td>-0.71</td>
<td>1.61</td>
<td>0.01</td>
<td>-0.442</td>
<td></td>
</tr>
</tbody>
</table>

*Note. SD = Standard Deviation*

This decrease in the holistic scores could be due to having different raters on the holistic scoring from pre to post. The increase in traditional scoring is a good sign that the games are contributing to improving the breadth and depth of knowledge into ethics and ethical decision making. Unfortunately, due to the low number of concept maps in the section that didn’t play games, a t-test could not be performed. A Wilcoxon signed-rank test was used on these concept maps instead. The Wilcoxon signed-rank test is a non-parametric version of a paired samples t-test and is used when the distribution is not normal [89]. The test works by assigning ranks to the magnitude of difference for each pair and then totaling the positive and negative ranks. Finally, the smaller total is compared to a test statistic, and it can be determined if the difference is statistically
A Wilcoxon signed-rank test was used and shows that there is no significant difference in any scores except for the number of hierarchies. Even though they are not statistically significant, the traditional scores did decrease within the group that did not play games. This may be due to many reasons such as students not taking the assignment seriously or not having enough experience with concept maps.

Table 15

*Concept Map Wilcoxon Signed Rank Test for Section without Games*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Z (Test statistic)</th>
<th>p-val</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Concepts</td>
<td>-1.053</td>
<td>0.29</td>
</tr>
<tr>
<td>Number of Hierarchies</td>
<td>-2.032</td>
<td>0.04</td>
</tr>
<tr>
<td>Highest Hierarchy</td>
<td>-0.962</td>
<td>0.34</td>
</tr>
<tr>
<td>Number of Crosslinks</td>
<td>-0.365</td>
<td>0.72</td>
</tr>
<tr>
<td>Traditional Score</td>
<td>-0.350</td>
<td>0.73</td>
</tr>
<tr>
<td>Comprehension</td>
<td>0.000</td>
<td>1.00</td>
</tr>
<tr>
<td>Correctness</td>
<td>-1.651</td>
<td>0.10</td>
</tr>
<tr>
<td>Organization</td>
<td>-1.510</td>
<td>0.131</td>
</tr>
<tr>
<td>Total Holistic</td>
<td>-1.916</td>
<td>0.06</td>
</tr>
</tbody>
</table>

*Text Analysis Pre vs Post*

Table 16 shows the pre and post concept map text analysis. 7 of the 10 concepts are the same between the two groups but the post group has consistently higher percentages of students that had the most frequent responses.
Table 16

Text Analysis of Pre Concept Maps Compared to Post Concept Maps

<table>
<thead>
<tr>
<th>Concept</th>
<th>% of students</th>
<th>Pre (n = 225)</th>
<th>Concept</th>
<th>% of students</th>
<th>Post (n = 232)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moral(s)</td>
<td>45.8</td>
<td></td>
<td>Moral(s)</td>
<td>50.9</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>34.2</td>
<td></td>
<td>People</td>
<td><strong>38.4</strong></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>28.0</td>
<td></td>
<td>Personal</td>
<td>34.5</td>
<td></td>
</tr>
<tr>
<td>Wrong</td>
<td>27.6</td>
<td></td>
<td>Others</td>
<td>32.8</td>
<td></td>
</tr>
<tr>
<td><strong>Values</strong></td>
<td><strong>26.7</strong></td>
<td></td>
<td>Right</td>
<td>32.8</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>22.7</td>
<td></td>
<td>Good</td>
<td>31.0</td>
<td></td>
</tr>
<tr>
<td>Personal</td>
<td>22.7</td>
<td></td>
<td>Consider</td>
<td><strong>26.7</strong></td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>22.2</td>
<td></td>
<td>Wrong</td>
<td>25.9</td>
<td></td>
</tr>
<tr>
<td><strong>Problem</strong></td>
<td><strong>21.3</strong></td>
<td></td>
<td>Work</td>
<td>25.9</td>
<td></td>
</tr>
<tr>
<td>Consequence(s)</td>
<td><strong>18.7</strong></td>
<td></td>
<td>Reasoning</td>
<td><strong>24.6</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Highlights show concepts that differ from each group.

The pre concept maps focused on “values” and “consequences” while the post concept maps focused on the “people” of the situation and “reasoning” to determine the best action to take. Ethical codes were brought up in 11.5% of the pre concept maps and 13.4% of the post concept maps, which shows a slight increase in what is seen as a paramount concept in professional engineering ethics. A previous study found that faculty and administrators hoped to instruct students with both guidelines such as laws and codes of ethics as well as construct their own ethical standards [38]. However, the students in this study did not include these guidelines, laws, or codes of ethics as major parts of their concept maps. This was surprising considering the importance that these
guidelines are within the area of engineering. A literature review of many papers focusing on engineering ethics education reported 85% of papers having codes of ethics and other such rules and regulations as a pedagogical strategy that was utilized [4].

**Text Analysis Games vs No-Games Section**

The text analysis for the two sections is found in Table 17 with 7 out of the top 10 concepts the same between the two groups. The games section had consistently higher percentage of students that used the most frequently used concepts than the no-games section. One interesting difference between the two groups is that the games section focused on “impact” of the decision where the no-games section focused on the laws. This may be because the games section used simulations that had students think about how they would act in a situation and therefore focus more on those affected by the actions. A quantitative study found seven metacognitive strategies that were used in ethical decision making: “(1) recognizing the complexities of one’s circumstances, (2) seeking outside help, (3) questioning one’s own and other people’s judgment, (4) dealing with emotions, (5) anticipating the consequences of actions, (6) looking within by assessing personal motivations, and (7) considering others’ perspectives” [87]. The concepts here show that students are utilizing some of these metacognitive strategies such as anticipating consequences and considering others. They are even acknowledging their personal motivations and those in the no-games group understands the importance of seeking help.
Table 17

Text Analysis of Games and No-Games Sections

<table>
<thead>
<tr>
<th>Concept</th>
<th>No-Games (n = 65)</th>
<th>% of students</th>
<th>Games (n = 167)</th>
<th>% of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moral(s)</td>
<td>43.1</td>
<td></td>
<td>Moral(s)</td>
<td>53.9</td>
</tr>
<tr>
<td>People</td>
<td>35.4</td>
<td></td>
<td>People</td>
<td>39.5</td>
</tr>
<tr>
<td>Personal</td>
<td>35.4</td>
<td></td>
<td>Personal</td>
<td>34.1</td>
</tr>
<tr>
<td>Others</td>
<td>30.8</td>
<td></td>
<td></td>
<td>34.1</td>
</tr>
<tr>
<td>Right</td>
<td>30.7</td>
<td></td>
<td>Others</td>
<td>33.5</td>
</tr>
<tr>
<td><strong>Value</strong></td>
<td><strong>29.2</strong></td>
<td></td>
<td>Right</td>
<td>33.5</td>
</tr>
<tr>
<td>Consequence(s)</td>
<td>29.2</td>
<td></td>
<td>Consequence(s)</td>
<td>30.5</td>
</tr>
<tr>
<td>Wrong</td>
<td>23.1</td>
<td></td>
<td><strong>Consider</strong></td>
<td><strong>29.9</strong></td>
</tr>
<tr>
<td><strong>Help</strong></td>
<td><strong>23.1</strong></td>
<td></td>
<td>Wrong</td>
<td>26.9</td>
</tr>
<tr>
<td><strong>Laws</strong></td>
<td><strong>23.1</strong></td>
<td></td>
<td><strong>Impact</strong></td>
<td><strong>25.1</strong></td>
</tr>
</tbody>
</table>

*Note. Highlights show concepts that differ from each group.*

**EERI/DIT-2 Pre vs Post**

The EERI data below shows that there was a statistically significant increase in the N2 value among the students. The DIT-2 data similarly shows a significant increase in both the N2 and P values among students across the semester.
Table 18

*Paired T-Test of Pre and Post EERI*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>-0.71</td>
<td>16.90</td>
<td>0.578</td>
<td>-0.042</td>
</tr>
<tr>
<td>N2</td>
<td>2.96</td>
<td>15.26</td>
<td>0.011</td>
<td>0.194</td>
</tr>
</tbody>
</table>

*Note.* SD = Standard Deviation

Table 19

*Paired T-Test of Pre and Post DIT-2*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>2.37</td>
<td>13.52</td>
<td>0.012</td>
<td>0.175</td>
</tr>
<tr>
<td>N2</td>
<td>3.73</td>
<td>12.10</td>
<td>0.000</td>
<td>0.309</td>
</tr>
</tbody>
</table>

*Note.* SD = Standard Deviation

When split between the games and no-games sections, the DIT-2 shows that the no-games section has a statistically significant improvement for both the P and N2 scores across the semester. However, games section, while both scores improved, they were not statistically significant. Previous studies have also found that the DIT-2 may not detect the growth of students’ ethical reasoning in the specific area of engineering [68]. The EERI shows a significant improvement in the N2 score for the games section, but not the
section without games. Although it is not statistically significant there is a slight decrease in P score for the section without games and a negligible decrease in the section with games. This shows that the games did slightly outperform the traditional instruction according to the EERI.

**Table 20**

*Paired T-Test of Pre and Post DIT-2 without Games*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>2.46</td>
<td>13.27</td>
<td>0.16</td>
<td>0.185</td>
</tr>
<tr>
<td>N2</td>
<td>3.91</td>
<td>11.71</td>
<td>0.00</td>
<td>0.334</td>
</tr>
</tbody>
</table>

*Note.* SD = Standard Deviation

**Table 21**

*Paired T-Test of Pre and Post DIT-2 with Games*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>1.94</td>
<td>14.87</td>
<td>0.44</td>
<td>0.131</td>
</tr>
<tr>
<td>N2</td>
<td>2.93</td>
<td>13.99</td>
<td>0.22</td>
<td>0.210</td>
</tr>
</tbody>
</table>

*Note.* SD = Standard Deviation
Table 22

*Paired T-Test of Pre and Post EERI without Games*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>-2.19</td>
<td>15.96</td>
<td>0.32</td>
<td>-0.137</td>
</tr>
<tr>
<td>N2</td>
<td>2.85</td>
<td>13.49</td>
<td>0.13</td>
<td>0.211</td>
</tr>
</tbody>
</table>

*Note.* SD = Standard Deviation

Table 23

*Paired T-Test of Pre and Post EERI with Games*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>-0.03</td>
<td>17.25</td>
<td>0.98</td>
<td>-0.002</td>
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<tr>
<td>N2</td>
<td>2.82</td>
<td>16.11</td>
<td>0.06</td>
<td>0.175</td>
</tr>
</tbody>
</table>

*Note.* SD = Standard Deviation

When split between groups of male and female the EERI shows significant improvements in both groups N2 scores, but not significant improvement in P scores. Although not significant, the female group did slightly improve in P score, but the male group went down slightly. The DIT-2 split shows that the male group increased significantly in both he P and N2 scores, but the female group only improved significantly in the N2 score. Although, the female group tended to score higher overall.
on the DIT-2, the larger improvement across the semester was seen in the male group. The EERI, on the other hand, shows a greater improvement in the female group across the semester compared to that of the male group. However, the effect sizes in all of these areas were quite low and shows that gender identity does not have a large impact on ethical reasoning growth. This finding is in agreement with previous research in this area [68].

Table 24

*Paired T-Test of Pre and Post EERI from Female Students*

<table>
<thead>
<tr>
<th>Variable</th>
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<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>0.60</td>
<td>16.07</td>
<td>0.75</td>
<td>0.037</td>
</tr>
<tr>
<td>N2</td>
<td>3.54</td>
<td>16.08</td>
<td>0.07</td>
<td>0.220</td>
</tr>
</tbody>
</table>

*Note. SD = Standard Deviation*

Table 25

*Paired T-Test of Pre and Post EERI from Male Students*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>-1.24</td>
<td>17.12</td>
<td>0.46</td>
<td>-0.073</td>
</tr>
<tr>
<td>N2</td>
<td>2.55</td>
<td>14.73</td>
<td>0.08</td>
<td>0.173</td>
</tr>
</tbody>
</table>

*Note. SD = Standard Deviation*
Table 26

*Paired T-Test of Pre and Post DIT-2 from Female Students*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>2.29</td>
<td>13.12</td>
<td>0.13</td>
<td>0.174</td>
</tr>
<tr>
<td>N2</td>
<td>3.57</td>
<td>11.93</td>
<td>0.01</td>
<td>0.299</td>
</tr>
</tbody>
</table>

*Note. SD = Standard Deviation*

Table 27

*Paired T-Test of Pre and Post DIT-2 from Male Students*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>p-val</th>
<th>cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>2.77</td>
<td>13.38</td>
<td>0.02</td>
<td>0.207</td>
</tr>
<tr>
<td>N2</td>
<td>4.08</td>
<td>11.95</td>
<td>0.00</td>
<td>0.342</td>
</tr>
</tbody>
</table>

*Note. SD = Standard Deviation*

*Multiple Regression EERI/DIT-2*

The impact of the demographic variables on the difference in scores between the beginning and end of the year for the EERI and DIT-2 were found using multiple regression analysis. Tables 28 and 29 show that with the DIT-2 and with the EERI, none of the demographic variables were found to be statistically significant. There was no change in scores based on the demographic variables of the students. Previous research
in this area has also come to the conclusion that gender and race do not affect the change in ethical reasoning amongst students [68].

Table 28

*Multiple Regression of Pre – Post EERI (n = 175)*

<table>
<thead>
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<th>p-val</th>
<th>t</th>
<th>p-val</th>
</tr>
</thead>
<tbody>
<tr>
<td>Games</td>
<td>-0.743</td>
<td>0.459</td>
<td>-0.058</td>
<td>0.954</td>
</tr>
<tr>
<td>Gender</td>
<td>0.715</td>
<td>0.476</td>
<td>-0.036</td>
<td>0.971</td>
</tr>
<tr>
<td>Institution</td>
<td>1.419</td>
<td>0.158</td>
<td>1.845</td>
<td>0.67</td>
</tr>
<tr>
<td>Race</td>
<td>0.308</td>
<td>0.758</td>
<td>0.102</td>
<td>0.919</td>
</tr>
</tbody>
</table>

Table 29

*Multiple Regression of Pre – Post DIT-2 (n = 210)*

<table>
<thead>
<tr>
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<th>t</th>
<th>p-val</th>
<th>t</th>
<th>p-val</th>
</tr>
</thead>
<tbody>
<tr>
<td>Games</td>
<td>0.516</td>
<td>0.606</td>
<td>0.087</td>
<td>0.931</td>
</tr>
<tr>
<td>Gender</td>
<td>0.109</td>
<td>0.913</td>
<td>0.048</td>
<td>0.962</td>
</tr>
<tr>
<td>Institution</td>
<td>0.420</td>
<td>0.675</td>
<td>0.074</td>
<td>0.941</td>
</tr>
<tr>
<td>Race</td>
<td>1.705</td>
<td>0.090</td>
<td>1.600</td>
<td>0.111</td>
</tr>
</tbody>
</table>
**Feedback Survey**

The clustered bar graphs in Figures 20 and 21 show a clear trend of students responding positively to the games in terms of holding their attention and being thought provoking. When combining both the strongly agree and somewhat agree, the game with the highest positive response for holding student attention was Cards Against Engineering Ethics with 124 students (83%) agreeing. The combined highest agreement for the game being thought provoking was Mars: An Ethical Expedition with 122 students (82%) agreeing. The lowest positive response was still high with 74%, or 111 respondents, agreeing that Cards Against Engineering Ethics is thought provoking followed by 75%, or 112 respondents, agreeing that Mars: An Ethical Expedition held their attention. Overall, this shows that students have a positive reaction to the games for both attitude and engagement. This response from students is expected when looking at prior research into student reactions to games being used as part of instruction within many subjects including engineering [9][8].
Figure 20

Student Responses to How Much They Agree that the Games Held Their Attention
The open-ended responses were read through by one researcher and themes were assigned for each response. When looking at the responses to Cards Against Engineering Ethics, one of the most common themes was that the game was fun, however, it did not focus as much on ethics. One student responded with “Fun game and it’s always a good time when you get to play games instead of reading off a ppt.”, while another said, “I didn't take the ethical decisions too seriously because of the answer cards.”. One suggestion for the game was “Maybe focus more on ethics and less on humor.”. The overall responses were mixed but show that students were generally engaged, but that
there is room for improvement in its learning outcomes. One of the outcomes of this game was to create ethical conversation around why cards are ethical or not, this was not completely lost on the students with one stating, “While playing the game, my group was trying to find the most ethically incorrect card so that we would go further in the game. The game taught us to look at the situations and recognize why some of those cards would go against the codes of ethics.”. This, however, was a single response and shows that there is room for improvement with how Cards Against Engineering Ethics is used within the classroom.

There were fewer negative responses towards the game Toxic Workplaces than there were to CAEE. The most prominent themes that came out in the survey for Toxic Workplaces were that they learned about decision making and identifying ethical situations within the area of engineering. Some examples of students learning and practicing decision making are found in responses such as “The most ethical choices are sometimes not the most obvious choices. Consider every side of a situation.” or “Introduced a lot of nuance into decision making and what constitutes an ethical decision”. Some students describe their understanding of ethics in engineering changing through the game. One student says, “It showed realistic scenarios in an engineering environment and how choices can result in a positive or negative outcome.”, while another states, “I was able to view real life examples and learn that not everyone has the same views as me.”. One interesting response was “Allowed me to learn a bit about what I personally believe when it comes to ethical decision making.” which shows that the student was looking through a personal lens of ethics rather than a professional ethics lens. This furthers the idea that engineering ethics education should focus specifically on
the difference between personal and professional ethics. Not all of the comments on this game were positive, with students believing the game could be improved with outcomes for different decisions.

Mars: An Ethical Expedition had recurring themes in the survey responses about students learning of the challenges inherent in engineering ethics as well as what goes into the process of decision making. Responses such as “You sometimes have to make hard choices as an engineer and as a leader.” and “there are many different scenarios that can be played out and a lot of choices that need to be made, it is difficult to pick the right one sometimes.” express the difficulty of dealing with engineering ethics. The theme of experiencing decision making is found in responses such as “There can be multiple directions one can take and there is not necessarily a ‘correct choice’” and “I learned that in some work environments things might go awry. In these situations, it is best to ask everyone about it and come to a logical conclusion.”. The game also seems to be effective in its design to place students in the ethical situations and play it out as real life. One student responded, “I liked the creativity behind the assignment and how it allowed us to think about ethics in certain specific circumstances.”. Another said, “The role-playing style of this game made it very engaging.”

While there have been some games designed to assist in engineering ethics instruction, they mostly only discuss the design and creation of the games rather than measuring their effectiveness [7][33]. This study investigated the effectiveness of the game-based instruction in three main areas, cognitive, affective, and social/cultural, as described in the situated and playful learning theories [52][58]. Overall, the three games seemed to be more effective in terms of student attitude rather than cognitive measures.
While there is some evidence to show that the games were effective in improving ethical reasoning with the Engineering Ethical Reasoning Instrument as well as ethical knowledge with the traditional scoring of concept maps, there is also evidence to show that they were not more effective than traditional instruction with the Defining Issues Test 2 and the holistic scoring of the concept maps. The greater difference in the EERI compared to the DIT-2 could be explained by the games focusing more on engineering ethical situations, which is what the EERI is more sensitive to. When looking at the demographic information, it was found that while female students had the higher ethical reasoning scores overall, the male students had a greater change in scores between semesters. However, this difference in scores was small and the multiple regression analysis found that none of the demographic variables, gender, race, or institution, had any effect on the change in student scores. When looking at the holistic scoring of the concept maps, the decrease in ethical knowledge across the semester could be explained by the use of different raters between the pre scoring and post scoring. It may also be the case that students did not put as much effort into the post assignment, due to the timing within their course workload. However, the games did shine in the area of student attitude. It is clear that there is an appreciation for the game-based instruction amongst the students in that it is an active learning strategy that is thought provoking and holds their attention. Much of the previous research in the realm of game-based learning has shown to improve student attitude and engagement [6][9]. The games have also been shown to be effective in their goal to situate students within ethical situations that apply to the field of engineering, as well as, situating them in a social learning context. There is still room for improvement with the games, however. One such improvement is making
them more realistic or to have them introduce and reinforce the difference between personal ethics and professional ethics.
Chapter 5

Conclusion

Implications of Work

This study focused on two major research questions, (1) How do first-year engineering students conceptualize ethics and ethical decision making prior to formal education in college and (2) Do the game-based learning tools work effectively as situated learning and playful learning strategies? If so, who do they affect and how? Data was collected from students at three different universities at the beginning and end of the 2020-2021 academic year and collected data in three main areas: ethical reasoning, ethical knowledge, and student attitude. The first round of data had students take a moral reasoning instrument, either the Defining Issues Test 2 (DIT-2) or the Engineering Ethical Reasoning Instrument (EERI), and then create a concept map on the topic “ethical decision making” at the beginning of the year. Half of the students then received game-based engineering ethics instruction while the other half received traditional instruction. The second round of data had students again complete the moral reasoning instrument and concept map assignment with the addition of responding to a survey to provide feedback from the students who received game-based instruction.

When investigating the ethical reasoning of first-year engineering students, it was found that the students performed similarly to their peers from previous studies, but due to the high ethical standards within engineering and its direct impact on society, engineering education should focus on improving ethical reasoning. It was also found that they did not have a complex understanding of ethics from their ethical knowledge.
measures. This is not surprising as the students have yet to receive formal education in engineering ethics, however, this can lead us to conclude what areas should be focused on in future instruction. The main areas in which a lack of comprehension can be identified is the relationship between engineering ethics concepts and the distinction between personal and professional ethics. Through the analysis of the concept maps, it was found that the students lacked an understanding of how concepts were interrelated with each other. This has been shown to be an extremely important aspect of education and is often said to be more important than the concepts themselves. The second area that should be focused on is distinguishing personal ethics from professional ethics. The concept map text analysis started to suggest that there was a reliance on personal ethics. However, if professional ethics are introduced and reinforced through engineering ethics education, the students will have a stronger foundation of ethical knowledge on which to rely when encountering ethical dilemmas.

When investigating the effectiveness of the game-based instruction, it was found that there was a resounding positive attitude from the students, but not much evidence to support the effectiveness of the games on the cognitive areas of ethical reasoning or ethical knowledge. A discrepancy was seen in the ethical reasoning instruments with the DIT-2 showing that the games were not effective in improving the student scores, but the EERI showed improvements in the section that played the games. And in terms of ethical knowledge, the concept map traditional analysis showed an increase in many of the scores, but the holistic analysis showed a decrease in a majority of scores. While it is difficult to determine the effectiveness of the games on ethical reasoning or ethical knowledge, it is clear that the games are successful in garnering a positive response from
the students. The responses to the feedback survey showed that students often agreed that the games were thought provoking and held their attention. Within the open-ended responses, there were many examples of students that describe having learned something about engineering ethics and having enjoyed each of the games.

Through the examination of the prior knowledge of students, education can be improved by limiting the scope of future instruction inward toward the areas that will lead to the best learning outcomes. This study has identified two important areas of engineering ethics education for first-year students: the interconnection of ethical concepts and the distinction and relationship between personal ethics and professional ethics. The understanding of how concepts connect with one another is an integral part of the way knowledge is built [85]. In order to grow students’ conceptual knowledge, the most important thing to focus on is the relationship between key ideas of the topic [83][84]. Many researchers in the area of engineering ethics education agree that professional ethics such as codes of ethics, laws, and regulations are a staple in regard to instruction in this field [4][5]. This study of professional ethics can also lead to greater ethical knowledge and an understanding of the social contract between engineer and society [34][5]. The hope is that with this information, educators can create a more tailored instruction of engineering ethics to create ethically responsible engineers. The examination of the game-based instruction was conducted to further the development of novel active learning methods in the area of engineering ethics. Through this research, the development of these styles of learning can continue to be advanced and spread within the community of instructors. The three specific games discussed can also be improved through the research presented here. The games may also be disseminated to
other universities and reach a wider audience than the schools that created them. Overall, the information here can be used to improve engineering ethics education for many students as they strive to be successful and ethical engineers.

**Limitations**

As with many studies, there are improvements that can be made to this study. To start, the data collection could be improved. The concept map assignment could have been more structured in its instruction of how to create a concept map. The assignment that was used in this study had instructions that gave students an example on the topic “French fries” but could be improved by having students create a practice concept map for instructors to give feedback on before starting the scored concept maps. This would address any issue with students not understanding how to make a concept map. The data could have also been improved with more responses and more consistent participation from the students. While the study had a lot of participation on individual responses for pre and post assessments, the number significantly dropped when looking at the number of pre and post-test pairings that completed both a concept map and moral reasoning instrument. That number continued to drop when investigating the more specific groups of sex and instructional method.

When scoring the concept map using the holistic scoring method, there were a few limitations. The first is that there were different raters for the pre and post data. There was also a difference in the education level of the two groups of raters. The pre data had four raters with three of them being at undergraduate level and one being at graduate level. The post data had two raters, both at graduate level. While there was a training session for the raters on how to score concept maps and a reference map, the
difference in education level may have caused a discrepancy in how the concept maps were scored. In the future, if there has to be different raters between the pre and post data, consistency between raters can be checked by having the post data raters score some of the pre concept maps in order to establish reliability. Similarly, there can be improvements in the way the survey was conducted. Due to the survey being created before the research, the questions were not designed specifically as a research instrument and therefore did not account for any bias. The questions may be seen as leading the students towards a positive response. The open ended questions were also not able to be fully analyzed and coded within the timeframe and no reliability was found.

A large limitation in this study is the scope only being across one academic year. Though the study is aiming to investigate the effectiveness of the game-based intervention within first-year education, the moral reasoning instruments may not be able to detect changes over that small a time frame. Along with that, the concept map assignment could be placed in a more ideal spot within the class. Currently, the concept map assignment is placed at the end of the academic year, however, due to many other projects and reports that are weighted more heavily in their classes, the students may not be putting the same amount of time or effort that they put into the first concept map they create in the early part of the year. The study may be improved by looking at the growth of students past the first-year instruction, however this would be more difficult in accounting for all the variables that influence their growth.

Finally, the study was limited by the already abundant first-year course curriculum. This study involved adding in three educational games on top of the already necessary instruction within a class. This required the instructors who volunteered to
administer the games to rework their course to fit the new instruction. This is an area in which we encountered some resistance and could be resolved with an easy-use implementation guide that allows instructors to learn to administer the games easily and effectively for one or two class sessions.

**Future Work**

This work is part of a wider grant that will continue working towards the creation of effective game-based instructional methods. The grant will continue to gather data in future first-year classes in a similar manner as this study, while making improvements that were discussed in the limitations section. It will also contain the addition of interviews with first-year students discussing their responses to ethical dilemmas in engineering situations. The current plan for the grant will continue collecting and analyzing data for three years. Part of the survey response contained a question asking students how to improve each individual game used in the ethics instruction. These responses can be used by the researchers and game creators to enhance the effectiveness and appeal of the games for first-year students. Further development of the student response survey may be helpful in detecting the aspects of the games that are most beneficial to learning outcomes. The use of further detailed responses or possibly the addition of interviews in which students break down their thoughts on each game can lead to improvements on these particular games as well as game-based instruction in other areas of education.

In addition to these alterations to the content and data collection, the study may benefit from following the students through their time in the university and measure their ethical reasoning and ethical knowledge as they are graduating. The use of the same
assessment methods will allow for an investigation into the ethical growth of students throughout their entire engineering education. Specifically, the concept map assessment will be a novel method for assessing the effectiveness of engineering ethics education as a whole and the moral reasoning instruments may be better suited for a longer spanning study. Future work can also look into how the concept map scores that focus on ethical knowledge relate to the EERI and DIT-2 scores that focus on ethical reasoning. It would be interesting to consider how these areas are related and if there is any correlation between them.
References


Appendix A

Concept Map Assignment

Directions
1. We are asking first-year engineering students to develop a concept map of “ethical decision making” at the beginning and end of the 2020/2021 academic year. This will enable us, the research team, to see how students’ conceptualizations of ethics changes throughout the first year.
2. Students will first brainstorm individually all possible things about ethical decision making that comes to their mind. This can be done informally by asking students to write concepts and ideas on a sheet of paper.
3. Next, you should explain how to develop a concept map by developing a map of your own! You can choose any topic of interest but we suggest the concept “French Fry”. This can be done as a class activity (see attached example).
4. Students will then have time to develop their own concept maps around ethical decision making.
5. Students may use a blank sheet of paper to draft their concept map, but they are required to use the “C-Map” software to create their map!
   1. Google “cmaps.ihmc” and select the first link “Cmap-IHMC”
   2. Follow the C-Map Instructions for how to use the software!
   3. The link is also supplied on the bottom of this page!
   4. PowerPoint Concept Map Overview (https://drive.google.com/file/d/1hQPTMxFBjC55E6KOZMAoLGSn2eADHnwl/view?usp=sharing), Engineering Unleashed Faculty Development (engineeringunleashed.com)
   5. Cmap Concept Map Construction (https://drive.google.com/file/d/15gAzHjE7yRF3fMiuLFywJ66_AXVF/view?usp=sharing), Engineering Unleashed Faculty Development (engineeringunleashed.com)

Please construct a concept map starting with anything related to the ethical decision making. Expand on your ideas as much as possible.

“French Fry” Concept Map Example for FY Students

- Starting at the center of the map, write the word “French Fry” and circle it (shown in light blue in the example). The word in the center is the only one provided to students when they prepare their own map. In their case they will be given “Ethical Decision Making”.
- Ask students examples of what they think about when you say the word French Fry (if they don’t have any ideas you can start off by following the example map included below)
- It is important to emphasize with the example how the branches will start at the center (where the word French Fry is located) and move outwards but then branches can interconnect with one another. Two examples of note from the map provided include
that cheese and gravy on French fries is called “poutine” and that “shoe string” fries are typically found at “fast food restaurants”. These examples are important for emphasizing how concepts can connect to one another.

- The map below is not comprehensive and can be expanded upon based on student suggestions.
- When you provide the students with the “Ethical Decision Making” prompt please do not provide them with suggestions as to what needs to be included. This should be a completely independent activity on the part of the students.
Appendix B

Example of Defining Issues Test 2 Question [24]

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

What should Mustaq Singh do? Do you favor the action of taking food?” Each
Appendix C

Example of Engineering Ethical Reasoning Instrument Question [64]

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

Would you lie to the child?”
Appendix D

Descriptive Statistics of Holistic Scoring

Table D1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.60</td>
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<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Correctness</td>
<td>2.03</td>
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</tr>
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<td>Organization</td>
<td>1.77</td>
<td>0.49</td>
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<td>3</td>
</tr>
<tr>
<td>Holistic Score</td>
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<td>1.17</td>
<td>3</td>
<td>9</td>
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</tbody>
</table>

Note. SD = Standard Deviation