NSF IUSE – Revolutionizing the Engineering Ethics Classroom: Using Digital Narrative & Data Analytics to Improve Learning & Assessment of Students' Ethical Judgments

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This project, supported by the National Science Foundation's Improving Undergraduate STEM Education: Engaged Student Learning (IUSE:ESL) program (Level 2), aims to serve the national interest by improving both educational interventions for and assessments of engineering students' ethical judgments. Ethical lapses in engineering practice have repeatedly resulted in loss of life, environmental damage, and public mistrust. From the Challenger and Columbia shuttle disasters to the Volkswagen emissions scandal, the Flint water crisis, the Boeing 737 MAX crashes, and the East Palestine train derailment, such failures continue to occur across engineering domains [1-5]. To help prevent such failures, educators and psychologists have long sought to assess ethical judgment through scenario-based tools such as the Defining Issues Test [6], Moral Judgment Interview [7], and Engineering Ethical Reasoning Instrument [8]. However, these instruments often emphasize abstract moral reasoning and third-person case analyses, which may not translate to real-world first-person decision making under pressure [9]. Building on theories of situated and embodied cognition [10,11], ethical judgment must be studied and cultivated in context-rich, first-person environments that mirror the complex, uncertain conditions of real engineering practice. Understanding how to better teach and prepare engineering students to make improved and more ethical judgments in practice will have broad, positive societal and economic benefits. To this end, this project includes a game-based engineering classroom intervention that immerses students in realistic, narrative scenarios where they must navigate complex ethical decision making and justify their personal choices. This foundation enables the present study's investigation into how contextual framing influences ethical judgment.

To examine how ethical judgment operates within a context-rich, first-person learning environment, this study asks: How does differentially contextualizing information in an ethical dilemma impact student judgment? The game-based educational intervention *Mars! An Ethical Expedition* (*Mars!*) is being used to collect a database of student narrative responses to engineering-contextualized ethical dilemmas. By changing the contextual information provided to different students surrounding the dilemmas, it was hypothesized that students can be induced to approach ethical judgments in a more situated manner. The digital format enables these contextual differences to be deployed efficiently to large cohorts, facilitating data collection and analysis of student ethical decisions through text-based responses and choice distributions.

Initial findings indicate that contextual framing can significantly influence students' ethical decisions. Our results suggest that significant framing effects occurred in three scenarios where contextual details about transparency, institutional precedent, or personal relationships measurably shifted students' choices. These findings support the view that ethical judgment is situated and context dependent, emerging from the specific details of each scenario rather than from fixed moral principles. However, additional research is needed to determine which effects are most pronounced, including the types of contextual clues and their placement within the narrative.

Introduction

This project addresses a long-standing challenge in engineering education: while ethics is a required component of accreditation and professional preparation, existing instructional and assessment tools often fail to capture how engineers actually make decisions under real-world conditions of uncertainty, time pressure, and competing obligations.

The primary goal of this project is to develop, deploy, and evaluate a game-based instructional and assessment platform that situates ethical decision-making in realistic engineering contexts. The platform, *Mars!*, is a digital narrative game designed for use in engineering courses. Through immersive storytelling and branching decision paths, students encounter a series of ethically complex dilemmas embedded within a cohesive professional narrative. Students must act as decision-makers, justify their choices, and experience the consequences of their actions within the evolving story world.

The project has two complementary objectives. First, it aims to improve ethics instruction by providing students with authentic, first-person experiences that mirror professional engineering practice more closely than traditional case studies. Second, it aims to advance ethics assessment by generating large-scale, fine-grained data on students' ethical decisions and reasoning processes, enabling rigorous empirical study of how context shapes ethical judgment.

Mars! is a narrative-driven digital game that situates students in the role of Commander of a newly established Mars base following a catastrophic infrastructure failure. The collapse of a supply bridge and communications array isolates the base, creating an environment of resource scarcity, political pressure, and heightened risk. Across a sequence of episodic chapters, players encounter a range of ethical dilemmas that require balancing safety, transparency, organizational rules, personal relationships, and long-term sustainability. Each episode presents a professional scenario grounded in authentic engineering and science ethics domains, including leadership ethics, business ethics, environmental ethics, sustainability, research ethics, and cyberethics. Students must decide how to respond to situations such as whether to disclose critical failures to the public, how to manage hazardous waste, whether to authorize invasive scientific research, and how to handle misconduct by trusted colleagues. Rather than evaluating abstract principles in isolation, students are asked to act as responsible professionals embedded in a complex organizational system. The game is designed for classroom integration and is deployed as part of regular course instruction. Students play individually and participate in reflection activities that encourage them to articulate their reasoning and consider alternative perspectives. The digital format enables consistent delivery across large cohorts while preserving the richness of narrative-driven learning.

Methods

To investigate how contextual framing influences ethical judgment, the project employs a between-subjects experimental design embedded directly within the game. Three versions of *Mars!* were developed, each presenting the same core ethical dilemmas but differing in the contextual information provided to players.

Version 0 presents the core dilemma only, without additional contextual cues. Version 1 introduces supplementary narrative details designed to encourage one decision option, such as appeals to transparency, empathy, or professional trust. Version 2 introduces alternative contextual cues designed to encourage the opposing option, such as references to institutional precedent, safety risks, or organizational consequences. Students are randomly assigned to one of the three versions prior to gameplay.

The game platform automatically records each player's decisions at all ethical decision points. In addition, students provide narrative justifications explaining their reasoning. After completing the game, students download a data file containing their playthrough information and submit it as part of their course assignment. Only students who opt in to the research study have their data included in the analysis.

This digital infrastructure enables large-scale deployment across multiple course sections while ensuring consistent experimental conditions. The result is a growing database of situated ethical decision-making data that supports both quantitative analysis of decision patterns and qualitative analysis of student justifications.

Results

Initial deployment of *Mars!* in first-year engineering courses has generated a dataset of 353 complete playthroughs (V0 = 108, V1 = 116, V2 = 129). For each of the twelve ethical dilemmas embedded in the game, decision distributions were compared across the three contextual framing versions.

Across scenarios in which contextual framing was held constant, no statistically significant differences were observed between versions. In contrast, scenarios that introduced meaningful contextual variation demonstrated selective framing effects.

One illustrative example is a transparency dilemma involving whether to disclose a catastrophic failure to the entire colony or restrict the information to a small leadership group ($\chi^2 = 34.85$, $p < .001$, Cramér's $V = .31$). In this scenario, contextual framing produced a medium-sized effect. When players were presented with narrative cues emphasizing the importance of openness and public trust, they were significantly more likely to disclose the failure to the entire colony. In contrast, when the frame emphasized past incidents of panic and disorder following disclosure, players were significantly more likely to restrict the information to a small leadership group. These results provide empirical evidence that ethical judgment is sensitive to contextual framing and therefore situated and emergent rather than solely principle-driven.

Implications

The findings of this project have important implications for engineering ethics education. First, they demonstrate that narrative framing can be used as a pedagogical tool to surface the situational factors that shape professional judgment. By presenting students with multiple framings of the same dilemma, instructors can help students recognize how organizational pressures, relational dynamics, and historical precedent influence their decision-making. Second,

the project advances ethics assessment by moving beyond static, vignette-based instruments toward dynamic, first-person scenarios that more closely resemble professional practice. The game-based platform preserves the scalability and standardization of traditional assessments while introducing ecological validity through immersive narrative design. Third, the project supports ABET ethics outcomes by providing students with repeated opportunities to practice ethical decision-making in realistic contexts [12]. Rather than treating ethics as an abstract add-on, *Mars!* integrates ethical judgment directly into the core engineering experience. Finally, the digital infrastructure developed through this project lays the foundation for adaptive ethics assessment tools that can provide individualized feedback and support evidence-based instructional design.

Conclusions

This NSF IUSE project demonstrates the promise of digital narrative as both an instructional and assessment tool for engineering ethics education. By embedding students in realistic professional scenarios and systematically manipulating contextual framing, the project provides new insight into how engineering students make ethical decisions under conditions of uncertainty, time pressure, and competing obligations. Initial findings indicate that while many ethical judgments are robust to framing, certain high-stakes dilemmas are highly sensitive to contextual cues. These results underscore the importance of situating ethics education within authentic professional contexts.

Future work will focus on expanding the deployment of *Mars!* across multiple institutions to support continuous improvement efforts. As part of this expansion, the *Mars!* platform will continue to collect both students' in-game decisions and their open-ended narrative justifications for those decisions, creating a growing corpus of situated ethical judgment data. This dataset will be used to refine instructional design and identify common ethical judgment patterns. Forthcoming iterations of the platform will also introduce adaptive feedback mechanisms to better support student learning. Natural language processing techniques will be integrated to analyze student justifications at scale, enabling more efficient and consistent assessment of ethical judgment across large cohorts. These efforts will support the development of adaptive, data-driven ethics education tools that both assess and strengthen students' professional ethical judgment.

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