Roleplaying Game–Based Engineering Ethics Education: Lessons from the Art of Agency

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Abstract

How do we prepare engineering students to make ethical and responsible decisions in their professional work? This paper presents an approach that enhances engineering students' engagement with ethical reasoning by simulating decision-making in a complex scenario. The approach has two principal inspirations. The first is Anthony Weston's scenario-based teaching [1]. Weston's concept of a scenario is a situation that changes in response to choices made by participants, according to an inner logic. Scenarios can dynamically explore open-ended complex problems without imposing predetermined results, allowing students to apply their ethical reasoning in a more realistic fashion. The second inspiration is Thi Nguyen's theory of games [2]. According to Nguyen, games are the "art of agency," meaning that they provide a structure under which some result is agreed to be valuable, along with prescribed ways of achieving that result, in a relatively low-stakes and temporary social arrangement. By playing many games, Nguyen argues, we can develop a "library of agency," that is to say, a set of values and means to achieving them that can inform how we make high-stakes decisions in real life. Engaging with carefully designed game scenarios, then, can enable students to practice making ethical decisions within a structured framework, which unfolds in response to their choices, while their decisions are driven by some defined goal. This roleplaying game–based approach thus allows students to build their own ethical libraries of agency, in preparation for professional decision-making. The approach is illustrated using a specific example recently deployed in a seminar on engineered living materials (building materials that incorporate living tissues). The scenario uses techniques from tabletop roleplaying games (e.g. *Dungeons & Dragons* [3]) for outcome resolution, adventure design, and character creation. Through the game, students practice making difficult decisions in a humanitarian context.

1. Introduction

It is common to say, in science, engineering, and beyond, that we learn best from our mistakes. A cornerstone of philosophy of science, for example, is Karl Popper's claim that we test hypotheses not by trying to prove that they are true, but by attempting to show, by counterexample, that they are false [4]. The scientific method, on his view, is the development of theories that attempt to explain observations, followed by attempts to disprove central claims in those theories through controlled experiments, leading to adjustment of theories which are to be tested yet again.

Echoing Popper, Henry Petroski writes that in engineering, the equivalent of a falsifiable hypothesis is the implicit claim made by the engineer that an artefact, system, or environment which they designed will not fail [5, pp. 44–5]. The stakes, however, are considerably higher:

> When I was a student of engineering I came to fear the responsibility that I imagined might befall me after graduation. How, I wondered, could I ever be

> perfectly sure that something I might design would not break or collapse and kill a number of people? …Since then I have come to realize that my concern was not unique… But if we were all to retreat with our phobias from our respective jobs and professions, we could cause exactly what we wish to avoid. It is thus that we practice whatever we do with as much assiduousness as we can command, and we hope for the best. [5, pp. 9–10]

In other words, while engineers, like scientists, may learn the most from errors, engineering errors can be catastrophic, whereas a scientific error might be limited in fallout to the academic context—notwithstanding applications of scientific error in practice.

As a result, professional engineers are in a position quite different from that of research scientists. They do not always have the luxury of attempting to disprove the soundness of their designs. Typically, they must do their best in the absence of well-developed scientific theory or controlled conditions. As Bill Hammack writes, the *engineering method* is "solving problems using rules of thumb that cause the best change in a poorly understood situation using limited resources" [6, p. 19]. This approach is distinct from the scientific method, which requires more precise approaches to problem solving, relies on better control of the situation, and assumes access to whatever resources are needed.

Much of engineering education is aimed at developing the student's assiduousness by inculcating rules of thumb and the technical skills and practice needed to improvise within acceptable parameters. But as both Petroski and Hammack repeatedly emphasize, the engineer's skillset goes beyond the technical. The higher stakes of failure combined with the inherent uncertainty of the engineering method mean that the engineer must have a sense of which risks are worth the anticipated rewards. The trust that stakeholders place in engineers means that engineers need to have a sensitivity to the needs and values of the communities they serve.

Thus, an essential engineering skill is an *ethical sensitivity*, a capacity described in the virtue ethics literature as an ability to perceive what is ethically required in this or that situation—in other words, a sense attuned to ethical reasons [7]. Aristotle emphasizes in his account of the virtues that ethical sensitivity is something that must be trained, that is, inculcated through education [8], [9]. And given the high cost of failure when professional engineers make ethical mistakes, it is all the more important that this component of their education occur in the low-stakes context of the classroom. Indeed, the educational context is a prime environment for developing professional ethical virtues, as Preston Stovall notes: "Our time in an educational institution allows us to engage in minor professional gaffes in a setting where the emphasis lies on our learning from these mistakes rather than having to professionally suffer from them" [10, p. 124]. Unfortunately, engineering curricula often give short shrift to ethical skill-building [11]. Worse, the principle that students learn best by *doing*, widely accepted in engineering as a truism (e.g. [12], [13], [14]), is often forgotten in ethical education.

The reasons for this misalignment between the importance of and attention given to ethics in engineering education are likely familiar to engineering educators: seeming lack of time in tightly packed curricula, lack of academic expertise in ethics among engineering instructors, lack of philosophically trained ethicists with an orientation towards practical ethics in engineering, and so on. Rather than analyze the reasons for these structural challenges, this paper presents a teaching approach that aims at partially resolving this alignment problem. For my working hypothesis is that a significant contributing factor is that there are insufficient exemplars of experiential, doing-based, (quasi-)realistic teaching approaches to engineering ethics.

The remainder of the paper develops an account of what a learning-by-doing approach to engineering ethics might look like. In §2, I outline the scenario-based teaching approach developed by Anthony Weston, a philosophy educator well-known for his innovative lesson plans. A more specific method emerges by considering Thi Nguyen's philosophical theory of games, which he describes as an art form which works on human agency; in §3, I present Nguyen's account and use it to extend Weston's approach. In §4, I illustrate the approach by presenting an actual lesson that I used in a seminar course on engineered living materials. Teaching materials from this class session are included in the Appendix. §5 concludes.

2. From "Sage on the Stage" to "Impresario with a Scenario"

It is now well-accepted by education researchers that lecturing is an ineffective method of teaching [15], [16]. The model of the "sage on the stage," who dispenses wisdom through their words to an audience, if only they have the attention and diligence to listen, simply doesn't help most students to achieve the desired learning outcomes. In its place, a wide range of different active learning strategies have been proposed, many of which show drastic improvements in students' ability to retain and apply information and skill.

In philosophy education, Anthony Weston is famous for a distinctive active learning approach he calls the "impresario with a scenario" or "teaching as the art of staging." He takes direct inspiration from dramaturgical traditions such as the *commedia dell'arte*, which incorporated a high degree of improvisation mixed with constraints set by a cast of stock characters and a rough outline of the plot. In his approach, the teacher is not the dispenser of wisdom into empty vessels, but rather the coordinator of actors in a play built around a structure rather than a script. The teacher sets some constraints, such as roles to be played and events to occur within a fictional context, but the specifics of the scenario emerge as a result of the participants' decisions.

Weston defines a scenario as a *dynamically structured situation*, that is to say,

> [S]ome kind of happening or state of affairs organized on a pattern known to all and at least partially revealed at the start… [which] progressively develops or unfolds following an inner logic that orients but does not completely determine the direction of the situation's movement or final resolution… enacted in a specific setting, such as a classroom. [1, pp. 46–7]

The dynamically unfolding state of the scenario works especially well with what philosophers call a *dialectical process*, where reasoning becomes increasingly complex and subtle through the consideration of different possibilities and justifications, alternative viewpoints, and clarification of concepts and arguments. As the scenario evolves, problems with initial opinions or lines of reasoning may become more apparent, different perspectives and complications may be introduced, and reasoning becomes more sophisticated.

An example Weston provides comes from a course he teaches at Elon University with astronomer Tony Crider. The course explores different ways of thinking about life in the universe, with a particular interest in the possibility and significance of life on other planets. An activity in the course has students take on a role analogous to researchers in the Search for Extraterrestrial Intelligence (SETI). These researchers have a uniquely challenging mission: to detect signs of intelligent life elsewhere in the universe, but without any understanding of what that life might be like or how it might communicate.

Students pre-read a famous article by Giuseppe Cocconi and Philip Morrison, which argues that the best approach would be to search for signals at the hydrogen line frequency which broadcast sequences of prime numbers. Their reasoning is that the primordial origins and ubiquity of elemental hydrogen would be obvious to any civilization interested in space, that radio waves are likely to be used by any civilization that develops telecommunications, and that sequences of primes would be a sign of intelligent life because they do not seem to be produced naturally [17].

This argument is clever and may be familiar to some students from science fiction adaptations of Cocconi and Morrison's idea. But the elegance of the reasoning belies the actual difficulties of SETI's challenge. To make the problem come alive, Weston and Crider begin the class with an odd challenge. They announce at the start of class that someone is trying to contact the students right now. That person knows that the class exists and is trying to make contact with them, but that is all. The class is then challenged to achieve two-way contact, using any means available.

The analogue to SETI's predicament is obvious to at least some students immediately. Inspired by the suggestions made by Cocconi and Morrison, they seek a common medium of communication—typically some combination of internet platforms—and begin looking for a message aimed at their class. In the first iteration of the activity, the stand-in for the space aliens was Weston's daughter, who achieved contact by leaving her contact information on Elon University's Wikipedia article. To close out the activity, the elder Weston made a Skype call to connect the earthlings and "extraterrestrial" so they could compare notes on the strategies they employed.

By actively engaging in the problem of making contact with another intelligent being with no information about their location, no certainty that they even exist, and only assumptions about their available means of communication, students become immersed in the epistemological challenge posed by SETI's mission. The reasoning behind Cocconi and Morrison's proposal—and perhaps flaws therein—become more clear once students confront a relevantly similar challenge themselves. Moreover, the students are in a better position to discuss further philosophically interesting issues posed by the possibility of extraterrestrial intelligences, such as the possibility of communication without a shared language, and the kinds of assumptions we make about possible alien life which are rooted in anthropocentric biases.

This scenario-based approach also highlights a lesson from the cognitive science of learning: we learn best by engaging in challenging applications of material some time after initial exposure to the knowledge, skills, and concepts to be learned. Effortful recall, unpredictable contexts of application, and dynamic life-like challenges all aid in consolidation of learning into long-term memory, and set up cues to aid recall in a wider range of situations [15].

In addition to the pedagogical benefits of a scenario-based approach, this method also enables the simulation of dynamic, unpredictable, (quasi-)realistic situations in which to practise ethical reasoning. At the same time, students can experience the consequences of their decisions without the real-life risk associated with professional engineering failures. However, some element needs to be included to make those consequences vivid and emotionally resonant. In Weston's example, this is achieved by having a real person the students are trying to reach. How can we achieve the same with regard to ethical decisions in engineering?

3. The Agency of Art

Our challenge is to apply the scenario-based approach to an engineering context, specifically to engage ethical reasoning skills, in such a way that students are engaged in somewhat realistic situations which change in response to their decisions, ideally in a way that encourages emotional investment in the outcome, while being actually low-stakes. As it happens, there is a prominent category of activities which are materially low-stakes yet emotionally charged, and come with features that can readily map onto Weston's concept of a scenario: *games*.

Gamification has attracted attention in the pedagogical literature as a strategy to engage students and simulate contexts requiring the application of learning [18]. However, the usual focus is on computer games, or gamification of learning with computerized tools. While these types of games can be effective learning tools, they come with often unacknowledged downsides.

For one, computerized gamification is often implemented to provide only superficial motivators. For example, a learning management system that merely awards "badges" or "achievements" for completion of learning materials may resemble the rewards structure of some games, but earning these prizes need not involve any game-like activity. It is "gamified" learning in only the loosest sense, and fails to fully take advantage of the technique.

For another, computer games are more constrained than other gaming media, such as tabletop roleplaying games or games played in improvisational theatre. Computer systems require pre-scripted logical structures, which limit the dynamism of the situation required in Weston's conception of a scenario. This scripted structure also renders the overall situation less responsive to creative solutions. While generative artificial intelligence applications may mitigate this limitation through their stochastic responses, this same feature means that they are notoriously bad at sustaining a narrative.

Finally, computer games introduce additional development costs, hardware and software requirements, and accessibility or localization concerns that may render specific applications of this approach untransferable between educational contexts. While both computer and tabletop games require design work and special materials, computer software must be precisely written to avoid errors (or total failure), and demands potentially expensive hardware to run. On the other hand, tabletop games can degrade gracefully if there are problems with their writing, and they need not require materials more expensive than paper, pens, and dice.

To better lay the groundwork for a properly scenario-based teaching game without these digital detriments, I turn now to Thi Nguyen's theory of games. Nguyen begins from Bernard Suits's definition: "playing a game is the voluntary attempt to overcome unnecessary obstacles" [19, p. 43]. For example, if what one really cared about when playing, say, *Monopoly*, was to have the largest collection of the game's currency, one could simply take it from the in-game bank. That one instead chooses to follow the rules for collecting these banknote simulacra shows that playing a game is unusual when compared with other kinds of activity. We willingly make it more difficult to reach some end state, and submit to some arbitrary means to achieving it.

Nguyen thus describes games of this kind as *inverting the usual structure of our agency* [2]. Usually, we adopt the most efficient means for an end that we value independently. For example, if I want muffins, I will adopt a means that is most likely to get me this desired foodstuff—going to the store to purchase some muffins, or, if I have the time and ingredients, mixing up a batter and baking it. But in a game, we choose instead to adopt an end that we likely would not otherwise care about, for the sake of engaging in an arbitrary means of achieving it. *Monopoly* money has no value outside of the game, yet when we play the game we do our utmost to maximize our collection of it, but only by following a peculiar set of procedures prescribed by the game's rulebook. Nguyen observes that *what we want is to play the game*, but the only way to do so is to act as though what we want are the things that the game tells us to value, and that the only way to get those things is to play the game. Finally, because we only desire them insofar as we want to play the game, the ends of a game also have uniquely temporary value. Once the game is over, we can pack it away and cease caring about *Monopoly* money.

Nguyen uses this theory to comment on a wide range of different games, ranging from board games (e.g. Go), to card games (e.g. *Magic: The Gathering*), to computer games (e.g. *Dance Dance Revolution*), to sports (e.g. racquetball), to avant-garde roleplaying games (e.g. *Sign*), to "stupid" games which "are only fun if you try to win… [but] the fun part is when you fail" (e.g. *Twister*) [2, p. 10], to activities not usually considered games but which have the same inverted motivational structure (e.g. rock climbing). These examples all serve to illustrate Nguyen's theory of games in Suits's sense: games are the *art of agency*, a unique artistic practice which uses human actions and motivations as its medium.

Unlike many advocates of gamification, Nguyen is interested in defending a distinctive kind of value had by games in themselves. Rather than merely seeking to employ games and game-like structures as means to achieving other ends, such as education, he seeks to defend the ways in which games have aesthetic and ethical value as such. Indeed, Nguyen is concerned that gamification can carry the risk of over-simplifying real-life values, which are subtler and more complex than what gamifications encourage us to pursue. Contrast, for example, that which a pedometer fitness challenge encourages—maximizing one's step count—with what this game is meant to promote—namely, health—and consider how these two ends could come apart.

On the other hand, though, Nguyen also praises the potential of games to expose us to a wide range of possible values and means of achieving valued ends:

> In game playing, we take on temporary agencies. These agencies have been shaped by others, and are passed to us via the game. In other words, games are a medium for storing and communicating forms of agency. A collection of games can, then, constitute a *library of agency*. [2, pp. 78, emphasis added]

Nguyen argues that playing games can help us to learn new ways of acting, new strategies for making decisions, and even new systems of value. By trying out different ways of using our agency through games, we can enhance our own personal autonomy and enhance skill development. This point again coheres with observations from the cognitive science of learning:

> Expert performance is built through thousands of hours of practice in your area of expertise, in varying conditions, through which you accumulate a vast *library* of… mental models that enables you to correctly discern a given situation and instantaneously select and execute the correct response. [15, pp. 83, emphasis added]

We can now see how a well-designed tabletop game can provide a dynamic and engaging educational scenario, which enables students to practice taking actions they might not ordinarily consider, in order to promote ends that they may not yet fully value. By playing a variety of such games, students may assemble a library of forms of agency. That is to say, they may learn what it means to value something in particular, and some of the strategies one might take to achieve it. The low-stakes practice involved in playing a game enables even highly dangerous engineering scenarios to be engaged with in safety, while still developing the ethical reasoning skills needed to make good decisions while on the job. And the emotional investment that playing a game produces also helps to *feel* that the stakes of the game matter.

4. Disasters & Decisions: An Engineered Living Materials Roleplaying Game

What does this look like, when put together in engineering ethics education? I now turn to an implementation of this theoretical framework that I created for an engineering course at Cornell University. This section offers summary information; the Appendix provides the teaching materials used.

The course was a graduate seminar on engineered living materials (ELMs), that is, materials that incorporate living organisms. Specifically, the class session for which I developed the following game was focused on a kind of construction brick made from water, plant fibers, fungus, and bacteria. The fungus provides structure for the brick, while the bacteria are genetically programmable to enable various features, such as changing color in the presence of contaminated water.

Prior to the class, students read a research article on this type of ELM [20], and consider several questions about the potential applications and risks of this ELM in particular and ELMs in general. One application the authors of the reading material suggest for their ELM is

> disaster relief, where it could be used to construct living structures from materials gathered on-site… These living structures might sense and respond to a variety of environmental signals relevant in such settings, such as heavy metals or cholera toxin present in the water supplies used to build the structure. And, once they are no longer needed, these structures can naturally biodegrade… [20, p. 477]

The class session thus opens with a brief lecture (about five to ten minutes) taking off from this potential application. There are ethical issues particular to humanitarian engineering which have been widely discussed in the professional ethics literature, including value conflicts between cultures, long-term maintenance of development projects, differences in professional structures and obligations between countries, political corruption, technology transfer, and so on [21], [22, pp. 169–87]. The lecture summarizes some of these issues to prime students' thinking.

The session then turns immediately to introducing the game scenario. The class is divided into small groups; each takes on the role of an engineering firm sent to assist the United Nations with an earthquake relief effort in a developing nation. They will be supplying and helping to deploy and manage an ELM similar to that which is described in the reading. Within the game, each group competes with the others to see who can achieve the highest score for "Community Health," an abstract measurement of their success in contributing to the relief effort. This aspect of the game provides players with the valued end they are to pursue.

Each group first chooses how to customize their ELM. The conceit is that they have limited time and resources to invest in developing a specific microbial culture before they must deploy it in the field. Each group receives a limited number of points to spend on attributes for their ELM, which each represent a particular capability of their material:

- Strength: Represents the ability of ELM organisms to grow, and the quality of the structures they build.
- Programming: Represents the quality of features engineered into the bacterial component of the ELM, such as toxin sensing and reporting.
- Biocontainment: Represents efforts taken to prevent ELM organisms from escaping into the environment, and to protect the ELM against infection.

These attributes are recorded on a "stat sheet." The process of creating the ELM is inspired by the character creation process in tabletop roleplaying games, such as *Dungeons & Dragons* [3].

The game then proceeds in a series of rounds. In each round, groups make dice rolls based upon their ELM's attributes to see how well their materials perform. The dice mechanic employed is inspired by *Blades in the Dark*, another tabletop roleplaying game [23]. For example, in each round, each group rolls based on their ELM's Strength attribute to determine how effectively their material builds and maintains structures in the disaster relief area. The use of a randomizer such as dice simulates the uncertainty of the engineering method, as well as difficulties which arise in rapidly changing situations like disaster relief, and the capriciousness of fortune. At the same time, the specific dice mechanic employed here drastically increases the chances of success when resources are invested in improvement of a particular attribute.

Each round apart from the first also requires groups to make an ethically challenging choice. For example, round 3 asks how their engineering firm responds to public and political concern about the long-term health and environmental effects of their ELM. They are presented with a choice between educating communities directly, or working to improve politicians' understanding of the technology. Each choice has consequences for their progress in the game. Educating the public substantially increases the group's community health score, but slightly reduces two of their ELM's attributes to reflect how much time and expense is involved in distributed education campaigns, which in a scenario with very limited time and resources comes at the expense of technical development. Choosing to lobby the politicians, on the other hand, results in a boost to the ELM's attributes thanks to increased investment, at the expense of a moderate drop in community health because misinformation about the ELM spreads to some communities.

At the end of the game, community health scores are compared, and one group is declared the "winner" of the game. But rather than lingering on this result, we turn instead to discussion of what they've just done. The instructor poses questions about whether any choices were especially difficult or easy, whether any felt morally wrong to make in some way, and how personal values and biases might have influenced their decisions.

By placing students in the midst of fast-paced decision-making in an unfamiliar context, they are made to engage their ethical reasoning as well as their recently gained knowledge of this type of ELM, integrating ethical and technical skills. The focus on community health orients them to a value that is not typically used to evaluate success in the engineering classroom, while the constraints on how they can influence the unfolding of the scenario require them to make wise decisions about both their ELM design and their interactions with different stakeholders. The result is a simulation of humanitarian engineering with emerging technologies that takes full advantage of the potential of gamification, and allows students to learn from their successes *and* failures. The hope is that this experience helps to fill out a neglected part of their library of agency, aiding them in ethical decision-making in their professional work. Informal feedback from the engineering instructor suggests that this was successful, as students were still making reference to the game in subsequent classes.

5. Conclusion

In this paper, I have elaborated an account of scenario-based gamified learning with the aim of providing a model for engineering ethics education. Leveraging the benefits of dynamically structured situations and the agency of art, this approach enables engineering students to practice ethical reasoning through engaging scenarios that reflect real-life, high-stakes engineering projects. Crucially, this approach also enables engineering students to learn from their mistakes in a personally impactful way, without the potentially harmful fallout of actual engineering failure. The approach was illustrated using a lesson developed for a graduate seminar on engineered living materials. However, in order for students to develop their library of ethical agency, a much greater range of lessons like this are needed. My hope is that this paper inspires teachers to create and share their own engineering ethics scenarios.

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Appendix: Disasters and Decisions

The following pages show the handouts and teacher materials used in the class described in §4.