Designing Lessons in Professional and Ethical Responsibility to Increase Student Engagement in a First-Year Course

David M. Feinauer
Virginia Military Institute

Abstract

This paper details efforts to develop skills related to professional and ethical responsibilities with first-year engineering students in an introductory course. The lack of domain knowledge first-year students have with respect to the engineering profession combined with a lack of shared contexts among the cohort makes it challenging for instructors to cover this topic in a meaningful way. The lessons described herein were designed to approach the topic in an active way that would feel similar to the students' experience with other engineering course content in order to draw the students into the exercises by building off shared experiences. The exercises draw on stories from commonly read texts, students' experiences going to the doctor, ubiquitous artificial intelligence, and the work-life of an alum from the engineering program. The motivation for, significance of, strategy for, outcomes from, and implications of the effort are discussed.

Keywords

Professional skills, engineering ethics, first-year engineering, active learning pedagogies

Purpose

In keeping with this year's conference theme of "educating principled engineering leaders of tomorrow," this paper details efforts to develop skills related to professional and ethical responsibilities with first-year engineering students in an introductory course. Many introductory textbooks and courses approach the topic of ethics and professional responsibility from the perspective of studying lists of rules, reading professional codes of conduct from the various engineering professional organizations, or reading case studies of infamous lapses in ethical behavior by society's engineers. In 2001, Perlman and Varman[1] characterized the landscape of engineering ethics education as being "filled with popular moral theories, notorious real cases, prepackaged ethical dilemmas, and ethics construction kits," while making a case for other approaches with a closer link to professional practice. Twenty years later, the landscape of support resources remains largely the same.

The lack of domain knowledge most first-year engineering students have with respect to the engineering profession combined with a lack of shared contexts among the cohort makes it challenging for first-year instructors to cover this topic in a meaningful and engaging way. As someone tasked with following the lead of other instructors who had chosen the pedagogical approach of developing rote knowledge of rules, codes of conduct, and potential pitfalls, this author can attest that teaching lessons of that type can be quite miserable for the instructor while simultaneously being disengaging for the students. Many first-year courses incorporate project-based, hands-on, active pedagogies in an attempt to achieve the technical and disciplinary student learning outcomes, yet they take the opposite approach for professional skills topics and

learning outcomes, including ethical responsibility. Students in these courses will recognize the disparity and see the professional topics that are divorced from the regular mode of operation as ancillary and less important. Said another way, if active pedagogies are important to achieving the technical learning outcomes with the constituents of a course, then they are important for achieving the professional learning outcomes in the same course with the same constituency. The author previously detailed[2] efforts to address students' perceptions of the engineering profession through introductory course activities developed in response to this pedagogical conception.

Through eight years of designing and evolving a first-year engineering introductory lecture and lab course for students from four engineering disciplines at Norwich University, and two years of developing and evolving a first-year lecture and lab course for electrical and computer engineering students at Virginia Military Institute, the author has employed multiple lessons related to professional and ethical responsibility. The lessons described in this paper were designed to approach the topic in an active way that would feel similar to the students' experience with other engineering course content and that would draw the students into the exercises by building off experiences shared by the cohort. This paper will detail engineering ethics lessons that were developed to draw on stories from texts in a first-year English composition course, students' experiences accessing medical care, an online "morality" simulator related to vehicular artificial intelligence, and an interactive eminent domain narrative based on the work-life of an alumni of the engineering program.

A brief discussion of the motivations for using active pedagogies, curricular design for student engagement, and challenges in engineering ethics education is presented in the Relevance and Significance section. The Strategy and Implementation section details the aforementioned lessons and extracts common components of the exercises that were collectively effective at promoting active student engagement. Observations and results from delivering the exercises are discussed in the Evaluation and Outcomes section. Lastly, lessons learned and recommendations related to future application of this approach are shared in the Implications for Practice section.

Relevance and Significance

In their study of intrinsic motivation[3], Deci and Ryan found that connecting one's work to greater contexts of significance or real-world applicability is a key factor in fostering an environment that supports high levels of self-motivation. Furthermore, they linked a sense of real-world connectedness or purpose to improvements in effort and performance. The study by Holt and Ohland[4] emphasizes the connection between active learning experiences grounded in one's discipline and improved student retention. Use of situative learning[5] approaches developed from professional and practical contexts that learners can relate to has been linked to improved student learning outcomes and persistence. Turning from the world of academic studies to consultancy think tanks, Deloitte[6] found that today's learners exhibit an increased desire to make an impact on society and an increased lack of patience for organizations or systems that are not doing so.

If engineers expect to be seen as principled leaders of yesterday, today, or tomorrow, then professional ethical responsibility and behavior must be engrained within the profession's ethos. While engineering educators recognize the need for educating students in engineering ethics, they frequently teach ethical awareness which does not always form future ethical actors or

leaders[7]. In their work developing a new educational framework[7], the authors acknowledge the current pedagogical foci of case studies, ethical codes, and moral theory in the engineering ethics classroom, and they cite empirical research supporting a lack of efficacy of said education. In a report on the Survey of Engineering Ethical Development (SEED) Project, Harding et al[8] assert that students make no gains in their knowledge of ethics as measured by a longitudinally administered survey composed of multiple choice test questions. With a bias towards active pedagogies, an acknowledgement of the challenges in the engineering ethics classroom, and an understanding of how real-world activities situated in the students' lived experiences can be both motivating and efficacious, the lessons described below were developed and implemented.

Strategy and Implementation

The approach taken in designing and implementing engineering ethics learning modules for a multidisciplinary first-year course was built on the key principles previously discussed: select situations derived from real occurrences (case studies), which intersect the students' lived experiences, and whose outcomes have the potential to make an impact on society. Once the situation and context is identified, the lesson needs to be attuned to the capabilities of the students and the desired learning outcomes—which included improving awareness and knowledge of ethical frameworks and professional responsibilities (the what) as well as facing a situation that challenges the learners as they work to act ethically and responsibly in a "gray" professional setting (the how). In effect, the strategy was to extend the case study approach that affords realism and authenticity to include broader issues than the specific or individual instances described in the case study while ensuring that the "correct" or "best" answer is not obvious. The context and lesson setup for four exercises that were developed and implemented with multiple cohorts of interdisciplinary engineering students are described below.

Cadavers as Crash Test Dummies Debate

Starting from a chapter of Mary Roach's *Stiff*[9], a novel assigned as part of an introductory composition and literature course, students learned about the history of the use of cadavers as crash test dummies, the genesis of the practice, and its modern decline. Students engaged in an initial debate over the past practice and typically divided along the lines of either supporting the practice at the time of the case described in the name of a "greater good" argument, or speaking against it in line with a personal virtue or "what kind of person would I become," argument. A question is then posed about the change in the size of the average adult male over time, and the lack of source data from non-adult males that informed the creation of crash test dummies. Students are placed in the role of ethical review panelists regarding whether to allow a window for the use of a larger cross section of adult and child cadavers as test dummies in the name of improved human safety and the creation of a new generation of crash test dummies.

GE Healthcare MRI for Children

Building off a human-centered design exercise shared at a Venture Well conference[10], an exercise detailing the GE Healthcare Adventure Series MR Imaging machines was developed. The scenario plays off the shared experience of a child's fear of the doctor or dentist. Data is presented such that the benefit to the child, the overall "good" of the solution, and reasons for adoption are plentiful. Students then assume the roles of various hospital executives convening to make a decision regarding the purchase of the device, with each person having access to part of the cost / benefit footprint of the solution. The most interesting pivot or surprise element is that

after the teams almost universally decide to adopt the obvious solution, they begin to question why they have not seen the solution more widely adopted. It is in response to their questioning that the facilitator prompts for an analysis of the ethical behavior of the board and an exploration of the reasons leaders might have for not adopting the solution.

Driverless Car Accident Scenario and the Moral Machine

After interacting with a popular, crowd-sourced platform that explores the "human opinion on how machines should make decisions when faced with moral dilemmas[12]," students explored the popular topic of driverless cars and the inevitability of the car detecting a forthcoming accident, and the ethical consequences that arise if one examines the car's actions following its awareness of an impending accident. The online platform is poised to explore many moral frameworks built on traditional ethical theories[13], such as: greater good, least harm, will of the people, freedom is paramount, or fairness test approaches. After discussing the intricacy and complexity of the scenarios answered by the students, the exercise turns to presenting the students with the specifics of an accident and asking them to explore whether the development engineers for the vehicular AI system should be held liable for the choice their autonomous vehicle made. Additionally, students were asked to personally reflect on how they would have navigated the responsibility of developing a product in line with a known moral framework that would lead to a result outside of their initial personal preference.

Eminent Domain and Romaine Tenney[14]

A media-rich presentation including first-person accounts and archival photos from a federal interstate eminent domain case involving Romaine Tenney was developed and interactively recounted to students in the course. At what appeared to be a peak of turmoil in the case, the story stopped and students were asked to write what the young engineer involved in the case should do, justifying their action plans. Following the reflection, the rest of the story was shared, taking a severe turn unexpected by most of the students. Following the denouement, students were asked to quietly reflect and share what they would have done differently, if anything.

Evaluation and Outcomes

Following the above synopses, analysis of the case study and active pedagogical approaches employed throughout the lessons revealed common attributes including: shared experience, real-world relevance, impact on society, knowledge of ethical responsibility, challenge to act ethically, and a surprise or audience "hook." Table 1 details and summarizes design and operational attributes that were key to the success of each learning experience.

In all instances of running the above lessons, the author was extremely gratified with the improved student engagement, expressed concern, and the maturity of student thought that became gradually apparent through the course of the exercises. It is worth noting that the cadaver exercise was the first of the four developed and it resulted from the author's observation of student hallway conversations in response to the "shock" of some of the excerpts they had read from the assigned novel. One of the reasons for the transition from that exercise to the others related to non-uniformity in the assignment of texts in the introductory comp. and lit. courses, and the difficulty of running that exercise when one of the less engaged sections arrived with a low completion rate of the assigned background reading. The assignment of background video

viewing, online survey taking, or participation in an interactive story-telling exercise had much broader participation which supported an improved classroom experience.

Table 1- Summary of attributes key to the success of the ethical engineering lessons described.

Lesson / Attribute	Cadavers	MRIs	Killer Cars	Eminent Domain
Shared Experience	Car safety; Driver education; Crash test dummy commercials; English comp. class exercise	Fear of doctor or dentist as a child; Use of an MRI	Awareness of Tesla and other self-driving car efforts; Assigned videos of self-driving car demos	"You can't stop the government" sentiment; Impact of construction / infrastructure improvements
Real-World Relevance	It happened / happens	Existing healthcare tech.	It happened; Public and not-so-public ongoing debate	It happened; Public stories and concerns ongoing
Impact on Society	Improved safety vs. respect for human body / remains	Improved healthcare outcomes vs. consumer appeal / opinion	Rise of artificial intelligence; Decision authority vs. responsibility for outcomes	Need for infrastructure to support growth vs. individual rights
Ethical Knowledge	Reference codes of ethics and moral frameworks	Reference codes of ethics and moral frameworks	Reference codes of ethics and moral frameworks	Reference codes of ethics and moral frameworks
Ethical Action (No easy choice)	Role on Ethical Review Board	Role on Hospital Executive Board; Reverse Engineering decision counter to the "obvious"	Role contributing to crowd-sourced data set; Role as design engineer facing a decision under much public debate	Role of young engineer facing uphill battle; Role of engineer facing a public tragedy
Surprise	Obligation to cleanup crews; Request to restart practice; Introduction of children	"Obvious" value far exceeds cost; Win-win with minimal common awareness / availability	Who "owns" the decisions of a robot? Question of responsibility / liability of designer	Extreme, public suicide; National attention; Firsthand account from an alum

It is also worth noting that while the general course was conducted with an open classroom door, when engaging in all four of the exercises described above, the conversation and debate piqued the interest of other engineering faculty members passing down the hall and frequently drew in

curious onlookers who were not members of the class. The ethical behavior exercises were one of a few professional skills activities that were developed in an active pedagogy that contributed to a self-expressed increased "understanding of the impact engineers have in larger societal contexts," increased "understanding of the role engineers play in keeping the population safe," and improved "ability to take initiative and act in a leadership capacity" by students in the courses as studied previously by the author[2].

When developing and teaching the introductory course for electrical and computer engineering students at VMI, the first instance of the course occurred during a semester with great pandemic restrictions, requiring the course lectures to be delivered in an asynchronous online format. As a result, a more traditional, non-active lesson and associated homework assignment was given to students in the class. During the second offering of the course, the classroom modality was in-person, and a blend of two of the active lessons was incorporated. On the final exam for both offerings of the course, three multiple choice questions about ethical responsibility were given to the students, the same three questions for both cohorts. Although the sample size of participants was small, and the offering of the contrasting styles of lessons was a result of teaching during a pandemic and not a designed educational experiment, the difference in the student attainment as measured by the multiple choice questions on the final exam was stark. Every student in the cohort who participated in the active learning lesson on engineering ethics answered all three ethics questions correctly. In the cohort who participated in the more traditional lecture-based lesson, only 2/3 of the students answered all three questions correctly. The remaining 1/3 answered 1 or 2 of the three questions incorrectly. Table 2 summarizes this information. This result combined with comments about the active ethics exercises obtained through various course feedback mechanisms, and the author's classroom experiences reinforce the author's opinion of the approach and its impact on student engagement, maturity of thought, and attainment.

Table 2 - Student performance on three ethics exam questions from two student cohorts.

Cohort	**Number Students**	**# All 3 Q's Correct**	**% All 3 Correct**
ECE First-Year Students w/ Ethics Lecture	21	14	66.67%
ECE First-Year Students w/ Active Ethics Exercise	18	18	100%

Implications for Practice

Over multiple years of a multi-disciplinary, lecture- and lab-based introductory engineering course focused on the development of both technical and professional skills, the inclusion of professional- and career-oriented content remained a polarizing topic among student opinion. The division was reflected annually in student course evaluations—the presence and approach taken with the professional skills content was one of the most common compliments and complaints about the course content and delivery. Students would commend their ability to engage in experiences they saw as directly related to becoming a "real" engineer, while others would deride the time spent on the efforts perceiving them as not "engineering."

While popularity among the masses has never been one of this author's personal, professional, or student learning goals, willing engagement among participants combined with post-reflection are key to success with activities in this domain. Motivations for the design, evolution, and overall effort associated with the creation of active course content related to ethical engineering practice include: the conviction that there should be coherence in the way disciplinary technical and professional skills are taught and practiced, experience that connecting content to purpose and shared experience supports improved learner motivation, and the belief that the professionally ethical path is to continue to challenge ourselves to improve our students' understanding of professional ethical responsibility and practice as we prepare them to be principled practitioners.

Anecdotally, the author can attest that another motivation is the number of students who have gone out of their way to individually, and personally express their thanks following completion of some of the activities described herein. One student sentiment that stands out years later, was from an upper division transfer student who was required to take the introductory course. The student expressed that although he had already taken the curricular-required ethics course from the philosophy department, he appreciated engaging in debate and conversation with an engineer and that he finally understood why the ethics course was required of him and his peers.

One challenge that must be addressed when implementing lessons of this nature is establishing the norms and expectation among the students that the classroom is a safe place for everyone to engage in debate and discussion of the sensitive topics of human import. It should not "go without saying," and if that type of discourse is atypical of the course, then the expectation should be actively and purposefully addressed. A second major implementation challenge is that sourcing relevant, relatable scenarios that are approachable by the audience is non-deterministic, and in two of the instances above was happenstance. It is the hope of the author that applying the guiding principles described herein and designing lessons to incorporate the key attributes of Table 1 should prove more realizable and result in a more rewarding student and teacher experience that emphasizes that engineering ethics is not ancillary to the study or practice of engineering. In an effort to continue to advance and affect students' abilities to address ethical dilemmas, the author is developing an activity related to the construction of the Panama Canal including the role played by an engineering alum of VMI, while working to incorporate principles detailed in the recent framework shared by Bairaktarova and Woodcock[7].

Acknowledgements

The author would like to thank Kelly Nolin, Director of the Norwich University Archives for her efforts in researching, developing, and engaging students in a thought-provoking, media-rich exercise about the eminent domain case of Romaine Tenney and NU alum Richard Haupt.

References

1 Perlman, B., and Varman, R. "Teaching Engineering Ethics." *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*, 2001.

2 Feinauer, D.M. "Redesigning an Introductory Engineering Course to Address Student Perceptions About Engineering as a Profession and Field of Study," *2017 FYEE Conference*, Daytona Beach, Florida, Aug. 2017. https://peer.asee.org/29432

3 Ryan, R. and Deci, E., "Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being," *American Psychologist*, July 2000, Vol. 55, No. 1, pp. 68-78.

4 Hoit, M. and Ohland M.W., "The Impact of a Discipline-Based Introduction to Engineering Course on Improving Retention," *Journal of Engineering Education*, Vol. 87, No. 1, 1998, pp. 79–85.
5 Johri, A. and Olds, B.M., "Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences," *Journal of Engineering Education*, 100: 151-185.
6 Deloitte, 2018 Millennial Survey: Millennials disappointed in business, unprepared for Industry 4.0, Deloitte Touche Tohmatsu Limited, UK, 2018. [Online]. Available: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/About-Deloitte/gx-2018-millennial-survey-report.pdf . [Accessed On: Nov 1, 2021].
7 Bairaktarova, D. and Woodcock, A. "Engineering Student's Ethical Awareness and Behavior: A New Motivational Model," *Sci Eng Ethics* 23, 11239-1157. 2017. https://doi.org/10.1007/s11948-016-9814-x
8 Harding, T., Sutkus, J., Finelli, C., & Carpenter, D. "Engineering culture and the ethical development of undergraduate students," *Proceedings of the research in engineering education symposium*, Palm Cove, QLD, 2009.
9 Roach, M. *Stiff: The Curious Lives of Human Cadavers*, New York :W.W. Norton, 2003.
10 Chang, D. "Workshop: I&E Iron Chef Activity Tasting Bar," *VentureWell Open 2018 Conference,* Austin, TX, Mar. 2018.
11 G.E. Healthcare. *Adventure Series U.S. Accessories and Supplies*. Waukesha, WI: GE Healthcare, 2021.
12 Awad, E. et al. *moralmachine.net*. Munich: Max Planck Society. Available Online. http://moralmachine.net Accessed on Nov 5, 2021.
13 Bonde, S. et al. "Making Choices: A Framework for Making Ethical Decisions," Brown University, 2011. Available Online. https://www.brown.edu/academics/science-and-technology-studies/sites/brown.edu.academics.science-and-technology-studies/files/uploads/Framework.pdf . Accessed on Nov 5, 2011.
14 Mansfield, H. "I will not leave | Romaine Tenney Loved His Vermont Farm to Death," *Yankee Magazine*, Dublin, NH: Yankee Publsihing, Inc. Issue: March/April, 2013.

David M. Feinauer P.E., PhD

Dr. Feinauer is an Associate Professor of Electrical and Computer Engineering at Virginia Military Institute. His scholarly work spans a number of areas related to engineering education, including P-12 engineering outreach, the first-year engineering experience, and incorporating innovation and entrepreneurship practice in the engineering classroom. Additionally, he has research experience in the areas of automation and control theory, system identification, and energy resilience fundamentals. His work has been published through ASEE and the Institute for Electrical and Electronics Engineering (IEEE); he is an active member of both organizations. He holds a PhD and BS in Electrical Engineering from the University of Kentucky.