The Future of Engineering Education
2024 Annual Conference & Exposition

Oregon Convention Center
Portland, OR . June 23 - 26, 2024

ASEE

Paper ID #43365

Advancing Engineering Ethics Education Using Active Learning

Dr. Rajani Muraleedharan, Saginaw Valley State University

Dr. Rajani Muraleedharan is a professor of Electrical and Computer Engineering (ECE), and the faculty advisor for IEEE Student chapter, Society of Women Engineers (SWE) at Saginaw Valley State University (SVSU), Michigan. Dr. Muraleedharan obtained her Ph.D. at Syracuse University. Her research interest includes wireless communications and networking, computational intelligence, robotics, behavioral science for autistic children, mobile-cloud computing, information and network security in autonomous heterogeneous networks.

Rajani is a strong advocate of diversity and women representation in STEM education, and is being recognized for her contribution at the 12th Annual Ruby Award for upward, bright and young from Great Lakes Bay Region and 'Young Professional Achievement Recognition Award' from NAACP Saginaw Branch in 2017. She volunteers towards making lives better for special needs children and adults using assistive technology.

Thomas Wedge, Saginaw Valley State University
Erik Trump, Saginaw Valley State University

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Abstract: In this paper, active learning strategies (role-playing) are employed to teach ethics to electrical engineering students for a holistic understanding of ethics violation and the moral responsibilities associated with seeking justice. An unconventional teaching method is explored that bridges the gap in applying ethical theory to case studies by enacting them. This approach enables students to understand the ethical dilemmas encountered in the profession and encourages them to seek support from authorized personnel rather than remaining bystanders. The research aims to empower students across various engineering programs to positively contribute to ethical responsibility by reevaluating their individual perceptions and embracing new perspectives for making moral judgements. The research outcome is evaluated based on a student survey collected over an academic year, which compares traditional teaching methods with active learning methods in terms of ethical understanding and team collaboration. The survey indicates that 92% of students strongly agree that learning ethics through role-playing leads to a better understanding of ethical responsibility, the impact of biased perceptions and social upbringing. Additionally, the survey suggests that to enhance students' ethical awareness, a student-centered active learning workshop focusing on the NSPE and IEEE code of ethics would be more effective than quizzes or case studies assignments.

Introduction:

In the modern world, engineers design and contribute solutions to many of the world's most significant challenges, ranging from saving lives to advancing technology to enhance the quality of life. Ethics is a crucial subject in any engineering program because today's students are the leaders and innovators of tomorrow who will be expected to behave in an ethical manner. Understanding the code of ethics established by the National Society of Professional Engineers (NSPE) and the Institute of Electrical and Electronics Engineers (IEEE) is essential because this understanding helps engineers demonstrate professional behavior that adheres to the highest principles of ethical conduct [1, 2]. However, teaching engineering students to develop ethical decision-making skills presents a challenge and requires innovative teaching methods.

Several challenges impact the teaching of engineering ethics, including minimal institutional support, limited prioritization of ethics in coursework [3], instructors' familiarity with ethics [4], and the cultural environment of engineering education [5]. Dissatisfaction with the traditional methods has led educators to introduce new ways to ensure that students can produce evidence that meets accreditation bodies' expectations of the ability to recognize ethical and professional responsibilities [6]. Thus, emphasizing the need for programs to prepare graduates with ethical awareness for the engineering workforce.

With the growing use of technology among students and the need for immersive learning practices, educators have introduced creative ways to increase engagement in engineering ethics in classrooms and professional development sessions. In this research study, an unconventional teaching method is explored that aims to bridge the gap in applying ethical theory to case studies

by enacting them. This method enables students to understand the ethical dilemmas encountered in the profession and encourages them to seek support from authorized personnel to save lives rather than remaining bystanders.

Background:

Ethics has been taught in engineering programs nationwide since the 1970s and one of the criteria set by the Accreditation Board for Engineering and Technology (ABET) requires engineering programs to incorporate ethics into student outcomes. There are primarily two conventional methods for teaching engineering ethics: the theory-based approach and the case-based approach. The theory-based approach emphasizes learning abstract ethical and moral theories. This method focuses on understanding the philosophical foundations and ethical frameworks that guide decision-making. However, one problem with this approach is its emphasis on theory over practice. Because students are not asked to apply these theories to specific situations, they are left uncertain about how to translate ethical codes and principles into actions in a real-world employment context. In the case-based approach, ethics is taught through the analysis of specific, often historical, incidents or fictional situations. This method vividly illustrates the consequences of ethical decisions by focusing on well-known engineering failures and crises, such as the space shuttle Challenger disaster, the Ford Pinto fuel tank issue, and the Hyatt Regency Hotel walkway collapse. Although intended as an improvement over the theory theory-based approach because it seems to provide students with tools and procedures, they can use to work through moral decisions they may face in their careers [7], this approach still has several limitations. Firstly, many of the cases used are several decades old, potentially leading students to view them as irrelevant to modern engineering challenges [2]. Additionally, these narratives often present key figures as heroic whistleblowers rather than portraying them as regular engineers who are simply fulfilling their professional and ethical responsibilities. This portrayal can lead students to perceive ethical behavior as exceptional rather than expected. A final limitation is the passive nature of the learning process in this approach. Students engage with these cases by writing analyses or taking tests, rather than by actively grappling with the ethical dilemmas presented. This passive engagement reduces opportunities for personal reflection and the development of critical thinking skills required in the students' future careers.

In recognition of the limitations described above, educators have recommended several strategies for increasing student engagement in engineering ethics: Some recommend electronic bulletin boards and chat rooms, which encourage students to openly share their experiences and seek advice, sometimes even with guest speakers from the industry who have been invited to participate in these forums to provide expert advice [2]. Many universities offer stand-alone ethics courses that students are required to enroll in as part of their degree program [8]. Some instructors tailor case studies that are specific to the engineering program of interest, which helps increase student engagement and discussion [9]. One innovative approach involves student skits; here, a case study is assigned to a student group to perform for their class [10], and in a reflection, students are required to complete a handout, identify the NSPE ethical codes being violated, and provide brief responses to open-ended ethical questions. A final strategy is game-based learning, where students earn points, badges, and leaderboards for their understanding of

ethics concepts as they progress through the game [12]. In this environment, students can vote on ethical responses to problems, choose ethically dubious options, or ask for other engineers' views on ethical responses to issues related to the field [13]. However, designing game-based learning environments requires institutional or other resources to create 3D virtual designs for contextually rich games.

Since the pandemic, first-time international enrollment in undergraduate engineering programs has shown steady growth at many US institutions [14], a fact that poses an additional challenge to traditional, writing-intensive approaches to teaching ethics. For many years, these programs have included an engineering ethics course as part of the first-year general education curriculum. Typically, the course covers normative ethical theories, a code of ethics, and three famous case studies: The Challenger Disaster, SDI: A Violation of Professional Responsibility, and Gilbane Gold. Students are assessed based on their report-writing skills, a method that can disadvantage international students. Additionally, senior students are expected to evaluate the ethical issues in their capstone project designs. However, the generic approach to teaching ethics often results in less student engagement and superficial learning [11]. Graduating students are expected to possess in-depth knowledge of engineering foundations and understand the technological and societal challenges to achieve sustainable engineering solutions. Currently, the exposure to engineering ethics limits students from engaging in non-technical aspects, lifelong learning, and culturally inclusive environments.

Engineering Ethics Educational Journey and Impact:

This study proposes two research hypotheses related to teaching ethics in engineering programs: (1) programs that include current technical challenges faced by the world help engineers understand the impact of modern technology and propose solutions considering public health, safety, and welfare; (2) programs that incorporate non-technical skills increase student engagement and inclusivity, enhancing the sharing of individual perspectives, which in turn increases students' professional responsibility in economic and societal contexts.

The electrical engineering program studied here has implemented a holistic engineering approach that incorporates both sociotechnical skills and engineering skills by integrating current ethical issues faced by society. This approach requires senior electrical engineering students to review current societal challenges and issues threatening sustainable solutions. It evaluates students' understanding of ethics through written technical reports and oral presentations that address the ethical issues in their capstone prototype designs, classes, and profession. However, engineering students still exhibit a lack of understanding regarding how cultural diversity and religious values influence ethical decisions. Embracing humanistic psychology within the curriculum helps students understand the importance of multiracial and socioeconomic communities, which directly influences ethical responsibilities and the impact of one's decisions on the community-at-large. This paper discusses the initial steps in implementing an effective engineering ethics education framework.

In collaboration between the Department of Theatre and the Department of Electrical and Computer Engineering, active learning strategies were developed to enhance engineering students' understanding of contemporary ethical issues and to foster lifelong learning skills. With institutional support for pedagogical innovations during the fall semester of 2021, theatre and engineering students collaboratively developed an engineering ethics skit. At the beginning of the semester, engineering student groups consisting of four members were formed with specific constraints: each group had to include one international student, and no two students could come from the same industrial affiliation. These constraints facilitated the formation of diverse student groups, reflecting varied cultural and professional backgrounds. To increase student interest and reduce professional distance, each group was required to select a case study that was no more than five years old and related to their program of study. After reviewing this issue as a group, they shared their findings with the theatre students.

Three theatre students were selected for this project based on their expertise in character development, skit writing, and directorial experience. These students interacted with three different groups, learning about three engineering ethics case studies. Due to funding and time limitations, they developed only one engineering ethics skit, and assisted in reviewing the script for the other two projects. However, a do-it-yourself (DIY) video was created, which future engineering students can use as a reference to develop their own skits, thereby fostering non-technical but lifelong creative skills. This DIY video enables engineering students to explore theatrical skills while role-playing and understanding the ethical dilemmas from one's perspective. The shared experiences of skit writing, rehearsal, and performance are utilized to develop and perform a creative skit, promoting a mutually inclusive learning environment for both engineering and theatre students.

The research outcomes from the academic year 2021 to the present include six engineering case study performances, which have been recorded to serve as engineering ethics examples for future freshmen in computer, electrical, and mechanical engineering programs. The instructional video was developed by theatre students to teach senior engineering students how to apply theatrical skills to create realistic engineering ethics videos, and as a baseline to create ethics videos with consistent learning outcome. These research findings support Computer Engineering (CpE), Electrical Engineering (EE), and Mechanical Engineering (ME) programs and can be integrated into any academic program to foster creativity while teaching strategies that promote ethical academic and professional behavior. The educational outcomes align with the EE department's strategic goals and the university's mission to provide high-quality academic programs, as demonstrated below:

1. Students demonstrate ethical decision-making and embody the attributes of an engineering profession.
2. Students majoring in Electrical Engineering and Theatre collaborate to educate their peers in ethical awareness and moral values.
3. Students acquire cross-disciplinary lifelong learning skills.

To assess the impact of student understanding of engineering ethics, a pre-post survey was conducted, evaluating three learning strategies: (1) analyzing current ethics cases and writing a technical report, (2) reviewing online resources (videos) and assessment based on an individualized test, and (3) active learning, which involved developing and performing a skit by the engineering student group and presenting an alternative ending to the class.

The surveys sought feedback from students on: (1) the impact of engineering ethics in their engineering education and career, (2) their preference for individual technical writing or group active learning

approaches, (3) their initial thoughts on the task of making a skit, and (4) their experiences in scriptwriting and skit development, as well as any remarks on the process. Additionally, the post-survey asked whether participating in the skit increased their ethical and social responsibility. The survey results revealed that all students firmly believed that engineering ethics is key to their career and profession. However, only 14% of the students preferred technical writing assignments. In the pre-survey, 29% of the students strongly believed that making the skit would be an easy task. However, the post-survey indicated that all students recognized scriptwriting and developing skits as tasks requiring creativity and appreciated the DIY instructional video.

The engineering ethics video repositories created by engineering students from 2022-2023 were shown to students in the following year (2024), and their feedback was insightful. Comments included, "They had some interesting information about case studies I had never heard of," "They did a much better job conveying the real situation in the case and an ideal outcome," and "They did a good job covering their issue, although sometimes it was slightly hard to hear." Clearly, the feedback indicates that students were impressed with the quality of the engineering ethics videos, the perspective of the narrators, and the complexity of the ethical dilemmas, which require a commitment to making thoughtful choices that align with ethical principles. These dilemmas also demand navigating with integrity and professionalism to achieve outcomes that positively impact the community at large.

The student feedback supports the research hypothesis: (1) there was an improved understanding of ethical dilemmas and individual perspectives on social responsibility, and (2) preparing for role-playing activities such as skit development and performance was challenging but improved student engagement. Since 2022, engineering students have overcome these challenges and learned new skills such as writing original scripts and performing based on ethical theory, professional attributes, and personal experiences. Additionally, student groups were encouraged to use standalone audio devices rather than their personal phones for video production.

In conclusion, early exposure to ethics during engineering education enables engineers to embrace professional accountability and social responsibility. Their actions and the objective moral principles apply universally across all people, cultures, and situations, suggesting that ethical absolutism can be achieved. Furthermore, a positive impact on the future engineering workforce [15], with unchanging principles and moral certainty, can be attained.

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