ER2: Preparing High School Teachers to Introduce Engineering Ethics Ideas

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Abstract

This paper presents the progress made in engaging high school teachers during Year 3 of a five-year NSF ER2 (Ethical and Responsible Research)-funded project focused on ethical research practices in science and engineering at a large public university in the southwestern United States. The project's broader objectives include assessing students' ethical research competency and self-efficacy, integrating ethics-focused learning materials into undergraduate engineering curricula, and providing enrichment experiences for high school teachers. This paper focuses on the Enrichment Experience in Engineering (E3) program, where six K-12 school teachers participated in a three-week summer initiative to integrate ethics into STEM education. Teachers were recruited from diverse school districts and regions, provided with room, board, and a stipend, and engaged in research, training, and curriculum development activities. They received instruction on and discussed topics of ethics, with an emphasis on science, technology, and engineering, developed lesson plans, and created posters showcasing their integration strategies. The participants also interacted with other E3 groups to explore best practices in engineering education. This paper describes the teacher selection process, program structure, and key outcomes, including ongoing discussions to assess the integration of ethics into their curricula. Lessons learned from this experience will inform future efforts to enhance ethical awareness in high school STEM education.

1. Introduction

Given the increasing importance of ethical practices in science, technology, engineering, and mathematics, early interventions prepare students for responsible research and professional conduct. This initiative aligns with the broader goal of promoting STEM ethics education as outlined in the NSF-funded project on Ethical and Responsible Research (ER2). This paper focuses on a key component of this project: enriching high school teachers' understanding of engineering ethics and empowering them to integrate ethics into their curricula. Teachers play an important role in shaping students' attitudes and competencies; thus, equipping them with the necessary knowledge is essential for effective ethical education at the high school level.

The following sections detail the steps undertaken during the summer of 2024 to involve six high school teachers in a structured program to provide an enrichment experience in engineering (E3) for K-12 teachers. The E3 program aimed to provide the teachers with hands-on experience in ethical research and practical methods to incorporate these lessons into their K-12 classrooms. The subsequent sections discuss the demographic distribution of the participants, training activities, outcomes, and the lessons learned from this initiative.

2. Enrichment Experience in Engineering for High School Teachers

The Enrichment Experience in Engineering program, offered during Summer 2024 at Texas A&M University, was a three-week program that brought together six K-12 school teachers from diverse backgrounds, each bringing unique expertise and experiences. The cohort reflected a balance in gender distribution, inclusivity in terms of participants with disabilities, representation of Hispanic/Latino educators and diversity in racial and ethnic groups, as summarized in Table 1. This diversity enriched the program by offering a wide range of perspectives on integrating ethics into STEM education.

Table 1: Demographic Data Summary

Category	Data
Gender Distribution	Female: 83.3% / Male: 16.7%
Disability Distribution	Yes: 33.3% / No: 66.7%
Hispanic/Latino Distribution	Yes: 16.7% / No: 83.3%
Racial/EthnicGroup Distribution	Black or African American: 33.3% / Asian: 16.7% / Do not wish to specify: 16.7% / White: 16.7% / American Indian or Alaska Native: 16.7%

The participating teachers taught across different grade levels and specialized in various STEM fields, including environmental science, robotics, computer science, chemistry, geology, and economics. Their teaching practices ranged from project-based learning to guiding students in advanced research, such as engineering capstones. Some were actively involved in directing district-wide STEM initiatives, fostering student engagement in extracurricular clubs like robotics and science fairs. Some participants worked with gifted and talented students, incorporating topics like renewable energy, sustainable development goals, and interdisciplinary approaches to economics and science. The program was designed to leverage these varied experiences, enabling the teachers to exchange ideas, collaborate on lesson plans, and develop strategies for embedding ethics in their teaching practices.

The program schedule integrated activities such as reading assignments, daily discussions with philosophy faculty, guest sessions with engineering faculty and experienced teachers, and lesson plan development. The program began with participants introducing themselves, sharing their backgrounds, and their goals and expectations for the experience. The reading assignments and discussions covered various aspects of ethics in science and engineering, drawing from key works on philosophy and technology [1], engineering ethics [2], research ethics and integrity [3][4], misconduct in science [5], the nature of technology and its implications for STEM education [6], and ethical problem-solving approaches [7]. Additionally, a session with the university librarian familiarized participants with the university's resources relevant to their curriculum development.

The second half of the program focused on independent research, guided by a philosophy faculty member, aimed at developing lesson plans. As part of the E3 program, participants were required to create and present a curriculum on engineering and research ethics for their class on the final day.

One participant proposed a high school curriculum emphasizing ethics in engineering documentation, teaching principles like honesty, integrity, and accountability. It introduces ethical documentation practices, case studies on unethical behavior, and hands-on activities where students document their design processes. Another proposal integrates engineering ethics and sustainability, focusing on carbon credits and the UN Sustainable Development Goals (SDGs). It involves collaboration with Kenyan scholars, designing sustainable solutions, and evaluating ethical practices. Assessments include surveys, carbon footprint analysis, and ethical rubrics aligned with NGSS and TEKS standards.

3. Analysis of Teacher Experiences and Outcomes in the E3 Program

The E3 program was designed to enhance high school teachers' ability and confidence to teach ethical principles in STEM. Feedback from the participating teachers, collected through pre- and post-program surveys, provides a clear picture of the program's impact. A Likert scale was used to measure their responses to various aspects of the program. The scale ranged from 1 to 5, with 1 indicating "Strongly Disagree" and 5 indicating "Strongly Agree." This method was employed to evaluate the teachers' confidence, preparedness, and perceptions both before and after the program, providing a quantitative measure of its effectiveness.

The E3 program had a notable influence on teachers' self-efficacy in teaching engineering ethics, as shown in Figure 5. Before the program, teachers were less confident about teaching ethical issues, answering student questions about ethics, and creating engaging lesson plans involving ethical topics than they were after completing the program. This indicates that the program helped in significantly building their confidence in handling ethics-related content in the classroom.

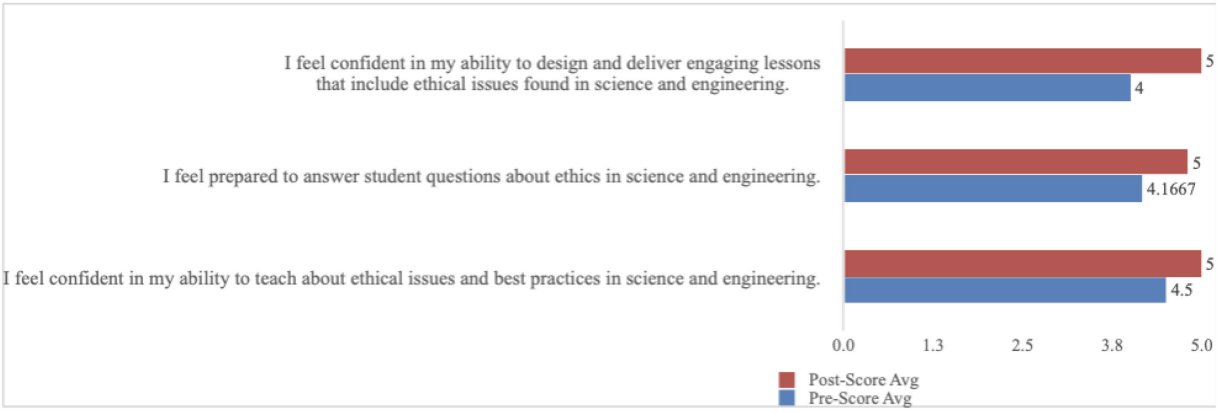

Figure 5: Teachers' self-efficacy before and after the program.

Preparedness to address specific ethical topics after the program is highlighted in Figure 6. These topics ranged from the societal impact of engineering to the ethical responsibilities of engineers and the importance of responsible research practices. Across all areas, the post-program responses indicated a clear improvement, with teachers feeling much more equipped to discuss and teach these concepts. This suggests that the E3 program effectively provided the necessary knowledge to help teachers integrate these subjects into their curricula. Teachers found the program highly beneficial, with aspects such as ethics-focused training, faculty collaboration, and lesson plan guidance being rated as 'Very Helpful' or 'Extremely Helpful' in post-program surveys. Overall, the findings demonstrate that the E3 program had a meaningful impact on teachers, improving both their confidence and preparedness to teach engineering ethics.

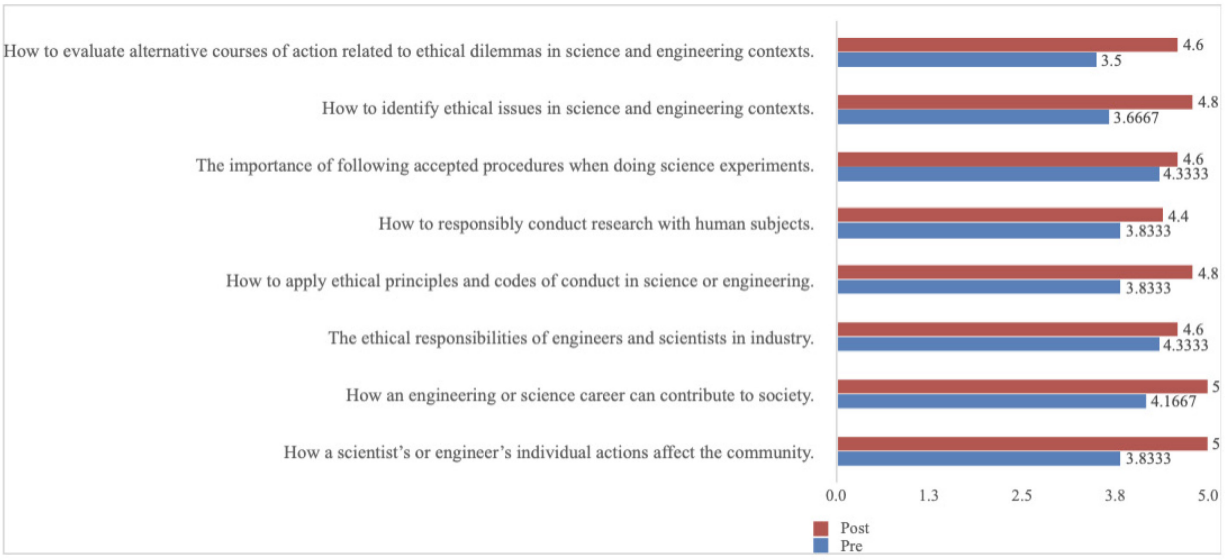

Figure 6: Teachers' preparedness for ethical topics pre and post-program

4. Conclusion and Future Scope of Work

The Engineering Ethics Enrichment (E3) program at Texas A&M University has proven to be a successful initiative in enhancing high school teachers' ability to teach ethical principles in STEM. By providing teachers with academic training, hands-on research experience, and collaborative curriculum development, the program significantly boosted their confidence and preparedness to integrate ethics into their classrooms. The positive feedback, as shown by the pre and post-program surveys, indicates that teachers developed a deeper understanding of ethics in science and engineering and gained valuable resources for teaching these concepts to the students. The diversity of the cohort, representing various disciplines and backgrounds helped achieve a broader range of perspectives during the discussions. The PIs intend to continue another cohort of teachers in summer 2025. The other ongoing activities of the project include development of supplemental learning materials on ethical engineering practices for sophomore and junior level courses and

continuous improvement of scale for assessment of ethical self-efficacy and ethical competency of the engineering students.

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