Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #46293

BOARD # 281: NSF IUSE: Integrating Ethical-Epistemic Pedagogy to Foster Moral Agency in Undergraduate Engineering Education

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Introduction and Literature Review

Engineering ethics has been a subdomain of engineering education for multiple decades, supported by accreditation entities like ABET and their desire to incorporate aspects of ethics into global workforce standards. As such, there have been a variety of studies on the efficacy of interventions for ethics education across a variety of scales including individual, institutional, policy, and cultural [1]. The notable variation in scope, scale and audience has made it difficult to determine "best practices" in engineering ethics education [1], [2] thus a consensus on effective practices for fostering ethics education remains tenuous. We seek to study whether ethical-epistemic analysis offers an avenue for strengthening engineering ethics education. This framework encourages students to consider ethical and engineering needs concurrently, rather than in isolation [3], [4]. Before detailing our approach, we begin by examining prior research that highlights the challenges engineering students face in engaging with their broader social responsibilities. We then outline a three-phase study supported by the National Science Foundation Improving Undergraduate STEM Education (IUSE) program.

Previous research indicates persistent difficulties in equipping undergraduate engineering students with engineering ethics skills. For example, scholars have found that some first year engineering students exhibit lower moral disengagement scores compared to non-engineering students using the same instrument [5]. Likewise, longitudinal surveys have suggested that engineering students are less interested in public welfare and societal impacts of their work at the end of their undergraduate career compared to the beginning [6], [7]. Numerous scholars have shown that many students fail to identify and contextualize real ethical challenges in engineering practice [1], [2], [8], [9]. The reasons for this seemingly disappointing progress in equipping students with ethical reasoning and moral agency are multifaceted. For example, Martin et. al. [1] lay out seven different challenges with student-level engineering ethics education including clarifying effective pedagogical approaches across various goals, covering diverse topics, conducting properly constructed assessments, using evidence-based materials, addressing unfamiliarity with the subject, overcoming limited support, and managing student resistance. As for the first challenge associated with the myriad of goals, there are at least twelve different categories of goals for engineering ethics education from developing moral sensibility, to moral judgement, to moral agency, and more [1]. Within our scope, we seek to develop moral agency in undergraduate students. In the context of engineering education, moral agency involves equipping students with the capacity to respond to complex challenges in a way that balances competing constraints responsibly [10]. It also emphasizes enabling students to influence the broader social, economic, and legal dimensions of their profession [11]. Beyond professional responsibility, moral agency encourages students to challenge the status quo, ultimately strengthening the engineering profession [12].

This research builds upon the idea that student ethical education can be enhanced when incorporating cases on real-world issues [13], [14], [15], [16]. Real-world case studies allow

students to discuss, debate, and construct different options [13], [15] while also remaining flexible and relevant in many contexts and classes [13], [14]. Unfortunately, numerous criticisms and questions have been raised by practitioners and academics alike about case-based pedagogy [17], [18], [19], [20], [21]. Several key critiques conclude that discipline-specific topics can fail to teach relevant ethical knowledge [17], [20], successful implementation depends heavily on the skills of the instructor [18], [19], [21], and that cases can deflect complexity in engineering practice [14], [17]. Despite the long history of case-based engineering ethics training, we are still struggling to develop undergraduate engineers who can identify real ethical challenges in engineering [1], [2], [9].

Moving beyond traditional case-based pedagogy, this project will incorporate the theory of coupled ethical-epistemic analysis and evaluate its effect on the development of ethical reasoning. While previous research has suggested that coupled ethical-epistemic inquiry advances knowledge around climate change [22], [23], [24], public health [25], environmental science [26], and research ethics [27], it has yet to be analyzed from a perspective of undergraduate student education. Coupled ethical-epistemic analysis, as envisioned by philosopher Tuana [3], [4], is a formal methodological approach motivated by the assertion that the landscape of difficult and wicked problems is itself complex and thus cannot be separated from the evidentiary resources, normative constructs, or human values we have for responding to these problems. Furthermore, this pedagogy is predicated on moving beyond traditional ethics training which often adopts some form of procedural ethics, that which refers to bad behavior in research or the workplace, and incorporates extrinsic ethics and intrinsic ethical thought [3]. In summary, traditional case-based pedagogy in engineering ethics often presents students with predefined scenarios and solutions, encouraging them to identify ethical issues but frequently limiting deeper exploration of how ethical and technical considerations interact. In contrast, ethical-epistemic analysis engages students in actively examining how knowledge production and ethical concerns are intertwined, fostering a more integrated and reflective approach to problem-solving. While case-based methods focus on recognizing ethical dilemmas, ethical-epistemic analysis challenges students to navigate the complexity of competing values within real-world engineering contexts, promoting more nuanced moral reasoning. Our project will extend understanding of how training focused on coupled ethical-epistemic analysis on topics of engineering relevance influences the development of moral agency by testing the efficacy of various coupled ethical epistemic analysis approaches in multiple contexts.

Methodology

This three-year research project will explore methods for integrating ethical-epistemic analysis across various contexts, including classroom instruction, undergraduate research experiences, and faculty development through a train-the-trainer model.

In Phase 1, we will train 10 undergraduate students over two semesters to apply ethical-epistemic analysis to climate adaptation plans from 15 megacities. Students will undergo systematic thematic analysis using Atlas.TI and refine their understanding of ethical and epistemic themes. Atlas.ti will be used to support abductive coding by combining both deductive and inductive

approaches. We will start with a set of predefined codes based on existing theories of ethical-epistemic analysis (deductive), applying them to climate adaptation plans. As students analyze the text, they will also identify new, emerging themes directly from the data (inductive). Atlas.ti's tools, like code co-occurrence and memoing, will help compare and refine these codes, allowing for a balanced analysis that incorporates both established frameworks and new insights. To measure their growth in ethical reasoning, a pre- and post-assessment framework based on reflective principlism [28], [29] will be employed, comparing students' baseline reasoning to their abilities after training.

Phase 2 integrates ethical-epistemic analysis into an undergraduate systems thinking course, focusing on embedding ethics into engineering problem-solving. Students will engage with formal ethical-epistemic processes and apply these concepts through case studies, such as artificial intelligence. A quasi-experimental design will assess ethical development, using pre- and post-surveys to compare enrolled students with a control group, measuring changes in moral development, diversity awareness, and ethical reasoning.

Phase 3 broadens the application of ethical-epistemic pedagogy through a train-the-trainer model. Fourteen faculty members across two summers will participate in workshops to redesign their courses using this approach. Faculty will create syllabi and teaching materials while receiving support from instructional experts. Pre- and post-surveys will evaluate the impact of these interventions on student ethical reasoning, ensuring the scalability and effectiveness of this pedagogical strategy across disciplines and instructors.

Results

To date, we have completed two semesters of undergraduate research employing coupled ethical-epistemic analysis and one semester of classroom data collection. Our results show positive changes in student scores on ethical principle identification, recognizing the ethical dilemma, assessing viewpoints across stakeholders, determining coherence across ethical principles to identify potential resolution, and reflective analysis of the proposed solution after completing a REU experience.

Through this initiative, we seek to contribute new insights into engineering ethics education by filling gaps in current pedagogy and identifying mechanisms that can enhance students' ability to address society-relevant issues. By presenting this work as a project-in-progress, we aim to generate discussion and feedback from the ASEE community, which will inform the next stages of implementation and further refine our iterative research design to better support student learning outcomes. This work aligns with the NSF's focus on improving the quality of undergraduate education and preparing students to meet the complex demands of the engineering profession with both technical expertise and ethical insight.

Acknowledgements

The author would like to acknowledge the anonymous reviewers and ASEE session chair for their time and input into this paper. This work is supported by National Science Foundation

Grant #2314334. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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