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Developing Moral Agency in Undergraduate Engineering Students: An Ongoing Exploration of Ethical-Epistemic Analysis Pedagogy

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Work in progress: an Approach to Integrating Ethical-Epistemic Analysis into Engineering Education

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Abstract

This work seeks to train engineers who are not just technically proficient, but are also more ethical and globally aware individuals. As part of this project, new educational strategies in undergraduate classrooms and research environments across multiple engineering disciplines will be piloted. Engineers today hold key roles in shaping our world and driving innovation. By developing engineers who are aware of and engaged with the ethical dimensions of their work, educators contribute to the creation of a workforce that values and serves societal interests. Our goal of presenting our project as a work in progress to this conference is to garner discussion and feedback on our design prior to project implementation furthering iterative research design and strengthening our approach to student learning.

This project brings coupled ethical-epistemic analysis from the field of philosophy and reflective practice from the field of cognitive design theory to the field of engineering education. This early-stage, exploratory project will study the effectiveness of leveraging adapted existing pedagogies (reflective practice) alongside new methodologies (coupled ethical-epistemic analysis) in multiple environments. This project seeks to fill gaps in existing engineering ethics education by testing new approaches and identifying potential mechanisms for cultivating engineers with broad moral agency and understanding of society-relevant issues. A variety of previous scholars have articulated the need for more research to build new knowledge as to why undergraduate engineering students are detached from the broader societal and cultural role of engineering and what types of interventions might reverse this trend. Across three tasks, this project will answer the questions: Does undergraduate research using coupled ethical-epistemic analysis influence the development of moral agency in undergraduate engineering students? Can coupled ethical-epistemic pedagogy in the classroom influence the development of moral agency in undergraduate engineering students? To what degree does variation in instructor and topic influence the efficacy of coupled ethical-epistemic analysis in undergraduate engineering courses?

Keywords

Engineering education, ethics, ethical inquiry, undergraduate, research experience

Introduction

The imperative to cultivate ethically minded engineers has never been more critical, given the increasingly complex and global nature of engineering challenges. Despite notable efforts and ongoing discussions within the academic and professional communities about the importance of instilling ethical behavior in undergraduate engineering education [1], [2], a consensus on effective practices for fostering moral agency remains elusive. The burgeoning interest in coupled ethical-epistemic analysis suggests a promising avenue for addressing this gap by enabling students to consider ethical and engineering needs concurrently, rather than in isolation [3], [4]. This approach not only offers a framework for integrating ethics into engineering problem-solving but also aligns

with the dynamic requirements of emerging STEM fields, marking a potential leap forward in undergraduate STEM education.

The urgency of this endeavor is echoed by national engineering organizations, which consistently advocate for enhanced ethical and global competencies among engineering graduates [5], [6], [7]. However, empirical evidence reveals persistent challenges in equipping engineering undergraduates with the moral agency required to navigate the ethical dimensions of their future professional roles effectively. Studies have indicated that some engineering students exhibit a decline in moral engagement over the course of their education [8], [9], [10], and many struggle to identify and contextualize ethical challenges inherent to engineering practice [1], [2], [11], [12].

In response to these challenges, this project seeks to transcend traditional case-based pedagogies by embracing theories of coupled ethical-epistemic analysis and reflective practice. This innovative pedagogical strategy is rooted in the recognition that real-world issues provide fertile ground for ethical inquiry [13], [14], [15], [16], and that ethical education can be significantly enhanced through engagement with cases that mirror the complexities of professional practice. Yet, criticisms of case-based approaches highlight limitations, including a lack of relevance to broader ethical knowledge and the substantial influence of instructor competence on successful implementation [17], [18], [19], [20], [21].

By integrating coupled ethical-epistemic analysis, we aim to address these criticisms head-on, offering a methodologically robust approach to ethical engineering education. This project is inspired by the potential of coupled ethical-epistemic inquiry to advance understanding across various domains, including climate change, public health, environmental science, and research ethics [22], [23], [24], [25], [26], [27]. Coupled ethical-epistemic analysis, as conceptualized by Tuana (2013, 2015), advocates for an integrated examination of ethical and epistemological aspects of complex problems, moving beyond procedural ethics to encompass intrinsic ethical considerations.

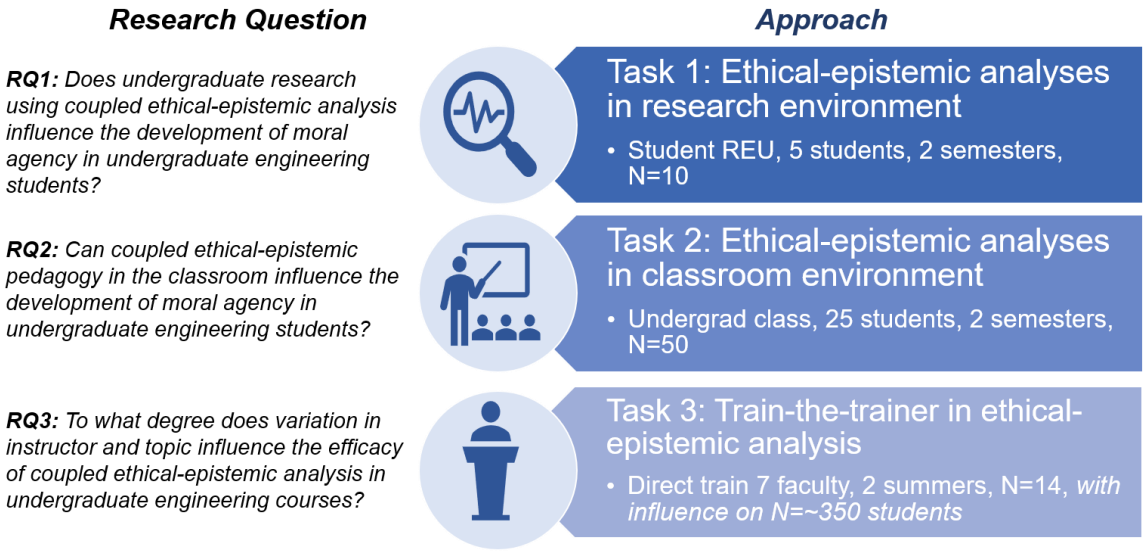
Furthermore, our approach derives from Schön's theory of reflective practice, which emphasizes the importance of action-based knowledge and regular reflection in professional practice [28], [29]. Applied to engineering education, reflective practice encourages a deeper engagement with the ethical dimensions of engineering design and problem-solving [30], [31], [32], [33]

This project is positioned at the intersection of these theoretical foundations, aiming to explore how coupled ethical-epistemic analysis can transform engineering ethics education. By conducting a pilot study with undergraduate students engaged in analyzing climate adaptation plans, we seek to understand the impact of this pedagogical approach on the development of moral agency, thereby contributing to the broader discourse on ethical engineering education.

Methodology

This research project will occur over the course of three years and will include approaches to integrating ethical-epistemic analysis across different domains including within the classroom, research experiences for undergraduates, and train the trainer for faculty (Figure 1).

Figure 1: Research overview and approaches



Phase 1: Integration of ethical-epistemic analysis within the undergraduate research environment.

For this phase, I will study 5 students per semester across 2 semesters within the undergraduate research environment. These students, majoring in any domain of engineering, will investigate the ethically complex topic of climate change adaptation, focusing on qualitative thematic coding of climate adaptation plans for 15 megacities.

The training regimen for participating students comprises a multi-step thematic analysis, adhering to established best practices [34], [35]. The process initiates with familiarization with the climate adaptation plan texts, facilitated by transferring these documents into the Atlas.TI software for systematic analysis. Drawing from previous research [23], [36] and relevant literature on ethical issues in climate adaptation [22], [26], we anticipate the emergence of initial codes reflecting coupled ethical and epistemic considerations alongside policy and engineering themes. Students will receive comprehensive training on code identification, the articulation of key ethical and epistemic themes, and the underpinning principles of coupled ethical-epistemic analysis.

To ensure rigor and reduce bias, two undergraduate researchers will independently code each adaptation plan. Subsequent review sessions will allow for the comparison and reconciliation of coding differences, fostering a collective understanding among the research team. The analysis will progress to higher-level thematic consolidation using LucidChart, facilitating a broader synthesis of the data.

The evaluation of students' ethical learning will leverage a mixed-methods approach, centering on scored rubrics designed to measure reflective principlism. This assessment framework identifies student reasoning across five domains: ethical principle identification, ethical dilemma recognition, stakeholder viewpoint assessment, ethical principle coherence, and reflective solution analysis [37], [38]. Initially, students will engage with a climate adaptation case, prompting them

to articulate their analytical and decision-making processes. This initial assessment, conducted before any training in coupled ethical-epistemic analysis, serves as a baseline measure of students' ethical reasoning.

Following a semester of focused REU activities, including training on coupled ethical-epistemic analysis, the ethical learning assessment will be repeated with a new case study to identify any shifts in students' ethical reasoning capabilities. I will independently evaluate student responses using the reflective principlism rubric, aiming to capture growth or changes in the designated areas of ethical reasoning.

Phase 2: Integration of Coupled Ethical-Epistemic Analysis in Classroom Environment

In Phase 2 of this project, I will introduce coupled ethical-epistemic analysis within the classroom setting through the undergraduate course. The draft objectives of the course have been crafted to ensure students gain a robust understanding of ethics and moral reasoning, recognize the ethical and epistemic facets of engineering problems, and apply these insights to enhance their professional and technical competencies. A significant portion of the course will be dedicated to teaching formal coupled ethical-epistemic processes, integrating these with each modeling component of the curriculum. Active learning techniques will be employed to contextualize ethical-epistemic analysis across various learning styles, with special topics, such as artificial intelligence, serving as deep dive case studies for the semester.

To assess the ethical development of students engaged this course, a quasi-experimental pre-test–post-test design will be utilized, comparing an experimental group (enrolled students) with a control group (non-enrolled students). The control group will be assembled through solicitation via email, with incentives offered for survey participation. Both groups will be roughly equivalent in size, ensuring comparability in the analysis. Data collection will be facilitated by Qualtrics software, with surveys distributed at the beginning and end of the fall semester. The surveys will incorporate the Moral Development Scale, Personal Beliefs about Diversity Scale, and Moral Disengagement Scale to evaluate various dimensions of ethical behavior and reasoning. These instruments, grounded in established theories of moral development and ethical behavior, will provide a comprehensive measure of student ethical growth and allow for comparative analysis with existing literature.

Analyzing the ethical behavior of participants will involve aggregating responses within each scale to facilitate literature comparisons. This process includes summing Likert scale responses, normalizing scores to reflect the 5-point scale, and examining distribution differences. A paired samples t-test will compare pre-test and post-test scores within both the experimental and control groups, focusing on gain scores to assess significant changes in ethical reasoning. This statistical approach will enable a nuanced evaluation of the pedagogical impact of integrating coupled ethical-epistemic analysis into engineering education. Through this methodological framework, the project aims to enrich students' ethical and professional responsibilities, offering a novel approach to integrating ethical considerations into engineering practice and research.

Phase 3: Broadening the Application of Coupled Ethical-Epistemic Pedagogy

This task will engage faculty from the School of Engineering and Applied Sciences, recruiting 7 faculty members over two consecutive summers (14 faculty total) through an email campaign initiated in early Spring. A stipend will be offered as an incentive for participation. Interested faculty are required to submit a brief summary detailing their interest in the workshop and the specific course they plan to integrate with ethical-epistemic pedagogy. Selection criteria will prioritize a diverse representation across disciplines, backgrounds, and career stages, should the number of applications exceed the available slots.

The week-long workshop will be structured to provide a comprehensive introduction to ethical-epistemic pedagogy, focusing on its background, pedagogical strategies, and course redesign principles. Each day will concentrate on a specific theme, facilitated through a combination of expert presentations, interactive group discussions, and individual planning sessions. Faculty participants will benefit from the expertise of the GWU Instructional Core team, which will deliver mini-lectures on active learning, student work evaluation, and effective course design, further tailored to the application of ethical-epistemic analysis in engineering education. By the end of the workshop, participants will have developed a ready-to-implement syllabus and preliminary lecture materials for their Fall courses.

To evaluate the impact of these pedagogical interventions on undergraduate student ethical development, this phase will incorporate a methodological approach similar to phases 1 and 2, utilizing a quasi-experimental design with pre and post-test surveys. These surveys will employ established tools for assessing ethical agency, complemented by at least one course assignment designed around the reflexive principlism rubric. This multifaceted assessment strategy will not only allow for a comprehensive evaluation of student ethical growth but also serve as a critical check on the research's integrity by examining the pedagogical efficacy across different disciplines and instructors. Through this broadened application and rigorous assessment of coupled ethical-epistemic pedagogy, Phase 3 aims to contribute significant insights into its versatility and impact on fostering ethical reasoning and moral agency among engineering undergraduates.

Results

At the current stage of our research, we are in the preliminary phases of implementing the proposed pedagogical framework and, as such, do not yet have empirical results to report. Thus far we have recruited 4 undergraduate research students to work on climate adaptation in megacities. We are utilizing this first semester to finalize our approach and test our structure on a selection of students before formal deployment.

The purpose of presenting this conference paper is to share the foundational structure and methodology of our study with the academic and professional community, inviting constructive feedback and dialogue on our approach. We believe that by outlining the design and theoretical underpinnings of our project, we can foster a collaborative discourse that may enhance the study's effectiveness and relevance. This engagement is crucial for refining our methods and ensuring that our investigation into the integration of coupled ethical-epistemic analysis within engineering education is both rigorous and impactful. Additionally, sharing our framework at this stage allows us to contribute to the broader conversation on ethical engineering education, potentially inspiring

others to consider innovative pedagogical strategies for cultivating moral agency in engineering students.

Within our conference presentation, we will not only highlight any preliminary results we have to date, but we will also share plans for future phases of this research project aimed at building ethical-epistemic pedagogy throughout the undergraduate curriculum at George Washington University.

Conclusion

By exploring the application of coupled ethical-epistemic analysis in engineering education, this study aims to contribute to the ongoing conversation around enhancing ethical reasoning among engineering students. The methodology outlined here provides a foundation for examining the efficacy of integrating this innovative pedagogical approach, with the potential to inform future practices in engineering ethics education.

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