# NSF IUSE: Engaged student learning through coupled ethical-epistemic pedagogy

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# 1. Introduction and Literature Review

Engineering practice often involves decisions on how evidence is defined, whose perspectives shape the work, and which values guide trade-offs. Cultivating moral agency in future engineers to integrate ethical reasoning with technical judgment is therefore central to addressing complex, real-world challenges. However, despite the emphasis on ethics education through multiple outlets such as accreditation boards, academic research, and engineering practitioners [1], [2], a consistent set of best practices for developing ethical engineers does not exist [3], [4].

Researchers have found that first-year engineering students show lower moral disengagement scores than non-engineering students using the same instrument, even though engineering ethics has been a subfield of engineering for several decades [5]. Similarly, longitudinal surveys have revealed that many engineering students fail to identify and contextualize actual ethical challenges in engineering practice [3], [4], [6], [7] and that they are less interested in public welfare and the societal effects of their work by the end of their undergraduate studies than at the beginning [8], [9]. This prompted studies to discuss the effectiveness of interventions for ethics education on a range of scales, including individual, institutional, policy, and cultural [3], [4].

The foundation of coupled ethical epistemic analysis is the idea that everything humans do, including academic research and engineering design, involves values and those values can be both ethical or epistemic in nature [10], [11]. Studies have not yet been examined from the standpoint of undergraduate student education, but research indicates that paired ethical-epistemic inquiry can build important knowledge about climate change [12], [13], [14], public health [15], environmental science [16], and research ethics [17]. Thus, this study aims to examine how training in coupled ethical-epistemic analysis on engineering-relevant topics shapes students' moral agency by testing multiple instructional approaches across contexts, intending to help future engineers in morally complex real-world work.

# 2. Methodology

In this short report, we preview ongoing efforts to develop a three-phase, mixed methods design to explore techniques for integrating ethical-epistemic analysis across various contexts, including classroom instruction, undergraduate research experiences, and faculty development. Guided by mixed methods design principles, we use quantitative assessment trends and qualitative implementation evidence as complementary forms of inquiry rather than treating either strand as independently sufficient for evaluating this complex pedagogical intervention.

## 2.1 Phase 1: Research Experience for Undergraduates

In this phase of the project, we implemented a two-semester REU sequence structured around coupled ethical-epistemic analysis. We used the first semester as a trial phase with five undergraduate researchers to pilot the program structure and assessment approach while students conducted qualitative thematic analyses of climate adaptation plans for megacities. We then launched the second semester with five additional undergraduate researchers as the first implementation experiment, and the methods reported below focus on that implementation semester. We plan to replicate this with a third semester REU, which would be the second implementation semester, in Fall 2026.

We hired and trained five undergraduate researchers to conduct qualitative thematic analyses across three climate-related projects: (1) use of artificial intelligence in natural hazard detection, (2) electricity balancing authorities' use of climate projections in planning, and (3) local food systems. Each project was led by a graduate student (PhD or master's), who provided technical supervision and weekly mentoring. All students participated in shared training sessions and research group meetings in addition to project-specific work. We trained students to use abductive coding that integrated deductive and inductive approaches: project leads provided predefined codes grounded in ethical-epistemic theory, and students also documented emergent themes from the data.

Across the semester, we delivered focused training sessions on ethical-epistemic analysis as well as other relevant topics for professional development including the use and misuse of AI tools, file and document management, literature search and management, and data visualization.

To examine changes in ethical reasoning, a pre- and post-assessment framework based on reflective principlism [18], [19]. This approach builds on evidence that case-based instruction can support ethics learning when grounded in real-world contexts [20], [21], [22], [23] and enables evaluation of how students identify and reason through ethical issues in disaster-related scenarios [24]. The pre assessment was administered at the start of the semester before ethics training and focused on the Jakarta subsidence and flooding crisis. Students responded to six prompts addressing distribution of risks and benefits over time, stakeholder interests and power dynamics, justification of a preferred course of action, key uncertainties and competing ways of knowing, decision-making under uncertainty, and reflection on how personal values and background shaped their reasoning. The post assessment followed the same structure and prompts and centered on deep-sea mining for critical minerals, with students asked to reason from the perspective of International Seabed Authority council members under uncertainty.

We scored both assessments using a rubric that evaluates reflective principlism and coupled ethical-epistemic analysis across six areas: ethical principle identification, dilemma specification, stakeholder perspectives, coherence and justification, reflective analysis, and explicit ethical-epistemic coupling. The rubric targets how ethical reasoning and epistemic reasoning are integrated in students' analysis [17], [19], [25], uses a 0-3 scale per category. Scores were compiled to compare pre and post performance at both the total and category levels. Students also completed the URSSA survey at the end of the semester [26] to capture students self-reported gains in skills, confidence, and mentoring experiences; Likert-type responses were converted to a 0 to 4 numeric scale within sections and summarized using mean scores [26].

### 2.2 Phase 2: Classroom based pedagogical approaches

Phase 2 embedded the pedagogy in three courses: two first-year undergraduate courses, Introduction to Systems Engineering and Introduction to Engineering for Undeclared Majors, and one graduate course, Systems Thinking and Policy Modeling. These courses were selected because they aligned with the project timeline and were taught by the study author throughout the implementation period. To examine changes in ethical reasoning, we administered pre and post case studies scored with a reflective principlism rubric to elicit students' use of formal ethical-epistemic processes and to characterize trends in moral reasoning and awareness of diverse stakeholder perspectives.

We also collected complementary student feedback through the institutional Office of Survey Research and Analysis. Across the three courses, 36 students participated (10 in Introduction to Engineering for Undeclared Majors, 8 in Introduction to Systems Engineering, and 18 in Systems Thinking and Policy Modeling), and all students completed both assessments. Student feedback response rates were 9 of 10 (90%), 6 of 8 (75%), and 13 of 18 (72%), respectively.

To support a quasi-experimental comparison, we also leveraged end-of-course feedback from three additional offerings taught by the same instructor in which the ethical-epistemic training and case studies were not incorporated. The number of students in the comparison group included 44 students (16 in Introduction to Engineering for Undeclared Majors, 8 for Introduction to Systems Engineering, and 20 in Systems Thinking and Policy Modeling. Student feedback response rates were 14 of 16 (88%), 3 of 8 (38%), and 17 of 20 (85%) respectively.

### 2.3 Phase 3: Alternative instructor approaches

Phase 3 of the project intends to replicate these approaches with alternative instructors, i.e. other professors at our institution not formally trained in ethical-epistemic analysis or ethics education. We are currently deploying this approach in one class as of Spring 2026 and intend to replicate it in other courses in subsequent semesters.

## 3. **Results**

Phase 1 results. We found students demonstrating improvement in several dimensions of ethical reasoning, including ethical principle identification, stakeholder perspective-taking, and reflective analysis, providing preliminary evidence of growth in moral agency. Across the five students initially hired, one undergraduate student discontinued mid-semester due to time-management constraints. As a result, four undergraduates completed the full pre- and post-set. Upon analyzing students' performance progress (total change normalized by the maximum possible rubric score), all four undergraduates showed performance improvement. The overall percentage improvements were 10.19%, 12.96%, 12.96%, and 15.28%. Table 1 summarizes the pre- and post-performance with respect to the six rubric sections. Overall the largest mean gain occurring in the coupled ethical-epistemic section (+1.19 on a 0-3 scale), which is expected given the students received training on this framework specifically.

*Table 1 Summary of pre- and post-performance*

| Rubric dimension (0-3) | Pre mean | Post mean | Change |
|---|---|---|---|
| Principle | 2.48 | 2.98 | 0.50 |
| Specification | 2.38 | 2.92 | 0.54 |
| Perspective | 2.67 | 2.82 | 0.25 |

| | | | |
|---|---|---|---|
| Coherence | 2.44 | 2.94 | 0.50 |
| Reflectivity | 2.48 | 3.00 | 0.52 |
| Ethical-Epistemic | 1.63 | 2.81 | 1.19 |
| Total score (0-18) | 14.06 | 17.56 | 3.50 |
| Overall (%) | 78.13% | 97.57% | 19.44% |

Given that Phase 1 is the most advanced in our analysis, we have further enumerated the methods and results of Phase 1 of this study in a separate full-length conference paper at this conference titled "Developing Moral Agency through Coupled Ethical-Epistemic Analysis in Undergraduate Research". We are currently undertaking the analysis of Phase 2 results. Initial findings indicate overall satisfaction in the courses increased when topics relating to ethical-epistemic analysis were incorporated into the course. We have not yet implemented a full experiment for Phase 3 and thus do not have results to share at this time.

Given the goal of the NSF Grantees Poster Session at the ASEE Annual Conference is to provided NSF-funded engineering education teams a venue to present project progress and outcomes and to connect with other researchers and educators, we have focused the remaining content of this paper on shared learnings useful to others in this context.

### 3.1 Shared learnings and implementation considerations

We learned quickly that doing empirical engineering education research at a small university comes with real constraints that are hard to avoid. The most obvious one is sample size. Across phases, our cohorts were limited by the scale of our programs and by how many students could realistically participate in a given semester. That meant we could not treat early findings as definitive or make strong statistical claims. Instead, we treated many of our outcomes as descriptive and proof-of-concept, and we relied on multiple forms of evidence to look for converging patterns rather than over-interpreting any single measure.

We also found that institutional realities often shape the study design more than the research team does. Course schedules, enrollment, and instructor assignments are largely outside our control, and they can make it difficult to adjust an intervention, run parallel sections, or keep a clean comparison condition from one term to the next. Even when we wanted to refine timing or change how an activity was delivered, program requirements and course coverage expectations limited what was feasible. In practice, we had to build flexibility into our plans and accept that implementation fidelity would sometimes be constrained by factors unrelated to the pedagogy itself.

Looking ahead to Phase 3, we expect the biggest challenge to be adoption. This phase depends on buy-in from other faculty, and we have learned that this is never automatic. Faculty interest varies with workload, departmental priorities, and comfort with ethics-focused instruction, and even supportive colleagues may not have time to adopt new materials without clear scaffolding and support. For us, that means Phase 3 is as much about relationship-building and practical teaching supports as it is about research design.

Finally, one of our most important lessons has been how quickly the learning environment changed because of large language models. When we wrote the grant, widespread student use of LLMs was not yet a defining feature of higher education; the proposal was developed around the same time that ChatGPT was first released. Our case study assessments are completed in person, so the pre and post measures themselves are not directly affected by LLM use. Even so, LLMs are front and center in students' thinking, and students consistently want to talk about how these tools should be used, what responsible use looks like, and what it means for agency when decision-making and reasoning can be partially delegated to an AI system. In response, we added LLM-specific training and structured discussion focused on appropriate use, verification and attribution practices, and the ethics of relying on LLMs in research and coursework, and we expect these conversations to remain necessary as students' familiarity with these tools continues to grow. Based on what we have seen in Phase 1 and Phase 2, we expect this to remain a necessary part of Phase 3 as well.

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