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The Engineering Ethics Coach: Integrating AI Chatbots to Strengthen Ethical Decision-Making in Engineering Economy

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Abstract

Integrating ethical reasoning into Engineering Economy courses is increasingly vital as engineering education emphasizes professional responsibility alongside technical competency. This study introduces the Engineering Ethics Coach, a custom AI chatbot designed to support case-based ethical decision-making within an undergraduate Engineering Economy course. Trained on the NSPE Code of Ethics and tailored case materials, the chatbot provided students with interactive guidance and formative critique without revealing solutions. Twenty-five students engaged with the chatbot in a structured ethical analysis exercise. The study evaluated student engagement, ethical reasoning outcomes, and performance comparisons with a prior cohort taught using traditional methods. Students using the Engineering Ethics Coach demonstrated higher engagement levels, cited ethical codes more frequently, and exhibited greater depth in ethical reasoning—differences confirmed through both thematic analysis and statistically significant cohort comparisons. Survey feedback also revealed strong student perceptions of the chatbot's role in fostering critical thinking and clarifying professional obligations. These results suggest that AI-supported tools, when thoughtfully designed and aligned with instructional goals, can enhance ethics education in engineering. Future work will explore refining chatbot interaction styles, expanding curricular integration, and adapting implementations across varied learning environments to support broader development of ethical decision-making skills.

1. Introduction

Engineering Ethics and Engineering Economy

The importance of ethical decision-making in engineering practice is widely recognized and reinforced through professional standards, accreditation criteria, and licensure examinations. Accreditation bodies such as ABET, alongside organizations like the Institute of Electrical and Electronics Engineers (IEEE), American Society of Civil Engineers (ASCE), and National Society of Professional Engineers (NSPE), emphasize that engineers must prioritize public welfare, uphold integrity, and maintain professional responsibility [1-3]. Ethical competencies are similarly emphasized in the National Council of Examiners for Engineering and Surveying (NCEES) Fundamentals of Engineering (FE) examinations across multiple disciplines [4-7], affirming the expectation that new engineers can identify and respond appropriately to ethical dilemmas.

Ethical reasoning is especially vital within the context of Engineering Economy courses, where students must navigate decisions involving trade-offs between cost, risk, safety, sustainability, and public impact. Engineering Economy teaches the principles of making sound financial and strategic decisions in engineering practice, yet these decisions often carry ethical dimensions—such as weighing lower project costs against potential impacts on public welfare or environmental sustainability. Integrating ethics instruction directly into Engineering Economy reinforces professional obligations and encourages students to view economic analysis and ethical responsibility as inherently interconnected. Recent efforts in engineering education have emphasized integrating ethics more explicitly into Engineering Economy instruction. Burns [8] highlighted how Engineering Economy naturally supports ethical analysis through its real-world decision-making focus, a trend reflected in modern textbooks [9], [10]. These developments reinforce the importance of preparing students to address ethical considerations alongside economic analysis.

Although case-based learning has traditionally served as a cornerstone of ethics education in engineering, it is not without limitations. Conventional case study approaches often rely on static scenarios and instructor-led discussions, which may restrict opportunities for individualized feedback and dynamic student engagement. Students may also struggle to fully connect abstract ethical principles to the evolving realities of professional decision-making. Addressing these limitations requires new strategies that promote active learning, personalized interaction, and deeper reflection on ethical responsibilities [11].

AI Chatbots and Enhanced Learning

As engineering education seeks to better prepare students for professional challenges, emerging technologies offer promising new tools for supporting ethical reasoning development. Artificial intelligence (AI) and digital platforms are already transforming the broader economy and workforce [12], and within education, AI-powered chatbots have been explored as innovative resources for tutoring, coaching, and skill development [13], [14]. Systematic reviews confirm that AI chatbots can enhance educational access, personalize learning experiences, and support student engagement across disciplines [15]. However, the growing influence of generative AI tools like ChatGPT has also raised concerns regarding academic integrity and appropriate use, particularly among younger learners [16].

Rather than viewing AI solely as a threat to traditional education models, recent efforts advocate for its responsible integration to enrich learning environments [11]. Strategies such as developing custom AI chatbots aligned with educational objectives offer pathways to maintain academic rigor while leveraging the strengths of AI technologies [17]. At the forefront of this movement, work presented at the American Society for Engineering Education (ASEE) has demonstrated the effective use of custom generative AI chatbots as course resources [18], [19], explored their role in fostering collaborative creativity [20], documented positive student perceptions of AI-assisted learning [21], and investigated their potential to strengthen critical thinking and problem definition skills [22]. Further studies emphasize that designing environments where students tinker with and critically engage with AI technologies can empower more thoughtful, ethical technology use [23].

Building on this emerging body of knowledge, this paper introduces the Engineering Ethics Coach, a custom-designed AI chatbot intended to enhance ethical reasoning instruction specifically within an Engineering Economy course. By facilitating interactive dialogues centered on professional codes of ethics and case-based scenarios, the chatbot offers students opportunities to dynamically apply ethical principles within the economic decision-making context. This study evaluates the effectiveness of the Engineering Ethics Coach in promoting student engagement, improving ethical decision-making skills, and supporting learning outcomes, extending earlier findings on AI-enhanced learning tools [24], [25], and contributing to broader discussions about responsible and thoughtful integration of AI technologies into engineering education [11].

2. Research Methodology

This study aimed to assess the impact of integrating the Engineering Ethics Coach, into an undergraduate Engineering Economy course. The methodology focused on evaluating student engagement, the effectiveness of the AI chatbot, and comparative learning outcomes.

Research Questions

Three research questions frame the interest and pursuit of this study:

- R1: Student engagement—To what extent does the integration of the AI chatbot enhance student engagement and active learning in ethical decision-making within engineering economy?
- R2: Effectiveness—How effectively does the AI chatbot facilitate understanding of ethical principles and their application to economic decision-making in engineering scenarios?
- R3: Comparative outcomes—How do learning outcomes from the AI chatbot enhanced activity compared to traditional methods used in prior semesters?

Participants

The study involved 25 students enrolled in a sophomore/junior-level Engineering Economy course at a public university. Students were pursuing various engineering concentrations within a general engineering program. The course instructor had taught this course in eight prior semesters, providing a foundation for comparing outcomes across cohorts. Most students had minimal prior exposure to AI tools in an educational context.

Students were organized into eight teams of three or four members. These teams were pre-assigned to balance skills and competency levels based on students' performance on the first exam, which covered reading material on ethics. Each team included at least one strong member, one average member, and one weaker member. Teams had already collaborated on earlier assignments, fostering familiarity and teamwork. The participants were predominantly male (80%), and the age range was relatively homogenous.

Development of the AI Chatbot

The Engineering Ethics Coach was developed using Open AI's ChatGPT 4o (GPT-4 Omni) and trained specifically on the four ethics cases used in the exercise, as well as a test case. It was also trained on the NSPE Code of Ethics for Engineers to ensure detailed knowledge of the various codes. The development approach was informed by emerging best practices in engineering education, where custom generative AI chatbots have been shown to enhance student engagement, promote deeper learning, and provide scalable educational support. Prior studies have demonstrated that tailoring chatbots to course-specific content can improve learning outcomes and foster meaningful student interaction [18], [19]. Drawing from these insights, the Engineering Ethics Coach was designed to critique student reasoning, guide ethical reflection, and simulate professional dialogue without directly revealing answers.

Procedure Followed

The research was conducted during a single semester, incorporating the AI chatbot into a case-based ethical decision-making activity. The procedure involved:

1. Pre-Activity Preparation: In a prior class session, the instructor introduced students to the NSPE Code of Ethics, emphasizing their responsibilities as engineers and discussing the importance of ethical decision-making. The instructor selected four NSPE cases based on their relevance to capital investment decisions and alignment with the principles of engineering economy. Each case also included elements of sustainability, which were intended to motivate students by connecting ethical decision-making with impactful real-world scenarios.
2. In-Class Activity: The exercise was conducted during a single class session. Each of the eight teams was assigned one of four ethical dilemmas derived from NSPE case studies, with each case

assigned to two teams. These cases emphasized trade-offs between economic and ethical considerations. At the start of the exercise, a brief demonstration of the AI chatbot's potential was performed using an example case not included among the four assigned cases. The demonstration aimed to familiarize students with the chatbot's capabilities. Teams were provided with access to an interactive speech app to enhance the chatbot's accessibility and facilitate more dynamic team interactions. Students were encouraged to document the challenges they faced but not uncertainties. Minimal guidance, such as prompt engineering strategies, was provided, allowing teams to explore and adapt their approach independently.

3. Post-Activity Reflection: Students completed individual reflection assignments to evaluate their learning and provide feedback on the activity's design and the chatbot's utility.

The steps used in the in-class exercise followed a described process shared with the student teams at the beginning of the exercise. Figure 1 illustrates the process flow and steps that were followed in the case study exercise using the Engineering Ethics Coach, and the data collected specific to the exercise.

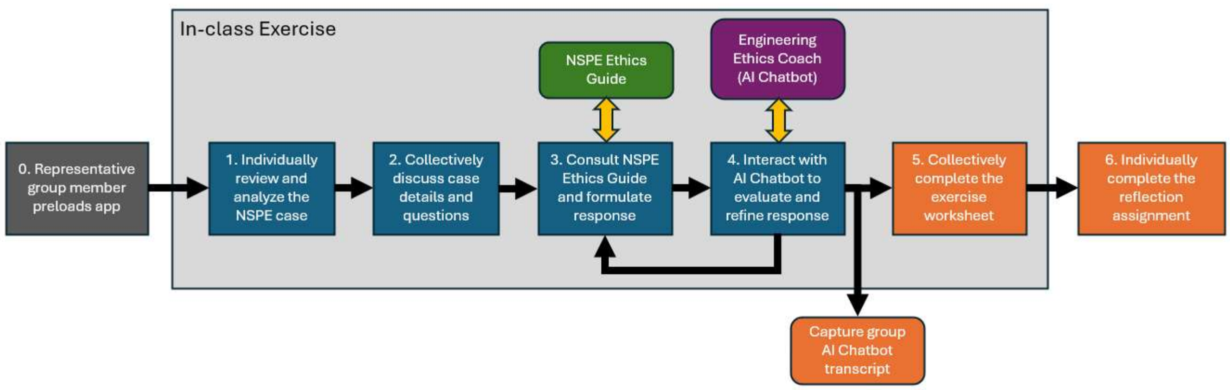

Figure 1: Process flow showing the steps in the case study exercise with the Engineering Ethics Coach

Additionally, a supplemental survey was administered to capture additional insights into student engagement and perceptions of the AI tool. This was collected one week after the exercise.

NSPE Case Studies

Each team was assigned one of the four published NSPE ethics case studies [26]. Each case presented an ethical dilemma involving a capital investment decision problem which was intertwined with a sustainability concern. The students were challenged to answer two questions about the case, which involved understanding the NSPE Code of Ethics. The cases are provided in Appendix B.

- Case 1: Avoiding Rolling Blackouts—An engineer must weigh replacing a fossil-fueled generator with solar panels, balancing carbon reduction benefits against increased blackout risks due to limited energy storage.
- Case 2: Public Welfare at What Cost?—A design revision could help a municipality upgrade aging water infrastructure more cost-effectively, raising ethical questions about balancing policy compliance with public welfare.
- Case 3: Climate Change and Infrastructure—A consulting engineer must decide whether to propose additional hydrologic analysis for a healthcare facility access road, factoring long-term flood risks linked to climate change into the project's immediate costs

- Case 4: Drinking Water Quality—Municipal engineers face pressure to switch a city's water supply source early, despite incomplete treatment upgrades, posing critical ethical and public health considerations.

Data Collection

Data was gathered from multiple sources to comprehensively evaluate the study objectives. This included chatbot transcripts, team exercise worksheets, individual reflection assignments, a supplemental survey, and a final exam essay question.

1. Chatbot Transcripts: Recorded interactions between student teams and the AI chatbot were analyzed to understand the types of questions posed, the chatbot's responses, and their influence on team decision-making. Transcripts did not include personal identifying data, and only team identifiers were retained.
2. Team Worksheets: Completed worksheets documented each team's analysis of their assigned case, including ethical considerations, economic recommendations, and references to the NSPE Code of Ethics.
3. Individual Reflections: Reflection assignments captured students' insights on the exercise, highlighting their understanding of ethical and economic principles and identifying areas for improvement.
4. Supplemental Survey: A post-activity survey collected data on students' engagement, perceptions of the chatbot's efficacy, and its relevance to engineering practice.
5. Final Exam Essay: Student responses to an ethics-focused essay question on the final exam were compared across the current and prior cohorts to evaluate learning outcomes.

Data Analysis

A structured approach was employed to analyze the collected data using a thematic analysis, quantitative metrics, and comparative cohort analysis.

1. Thematic Analysis: Qualitative data from transcripts, worksheets, and reflections were coded and categorized into themes, including ethical reasoning, chatbot interactions, team dynamics, and learning outcomes.
2. Quantitative Metrics: Engagement scores, chatbot usage patterns, and alignment with the NSPE Code of Ethics were measured. Comparative analysis highlighted differences in student performance across themes.
3. Comparative Cohort Analysis: Data from the current cohort were compared to those from a previous cohort that engaged in traditional case study exercises without the AI chatbot. Metrics included the number of ethical principles referenced, quality of recommendations, and depth of ethical reasoning.

3. Results

3.1 The In-class Exercise Results

The in-class exercise provides three outputs analyzed in this section: (1) the AI chatbot transcript of team interactions; (2) the completed exercise worksheet by the team; and (3) the completed reflection assignment by individual members of the team. These outputs provide evidence for research questions R1 and R2. First, summary results are presented from the completed exercise worksheets. Second, results from a thematic and quantitative analysis are presented using all three outputs.

Team Exercise Worksheet Results

Evaluating how well teams perform in this exercise can be summarized by the number of NSPE ethic codes correctly identified through interaction with their team and the AI chatbot. When this exercise was performed using traditional team-based case study historically the percentage of correctly referenced codes hovered around 40%, at best. Figure 2 illustrates results for the teams using the chatbot interactively to investigate their responses for the case study they were assigned. The mean value for the percentage of ethic codes referenced correctly is 58.0%. Figure 3 illustrates results by case. The mean value for the percentage of ethic codes referenced correctly, by case, is 58.0%. These results suggest that interactive AI chatbot exercises improve student engagement and ethical reasoning.

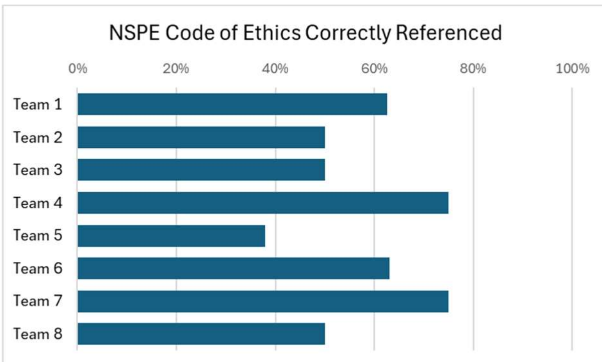

Figure 2: Percentage of NSPE ethic codes correctly referenced by student teams

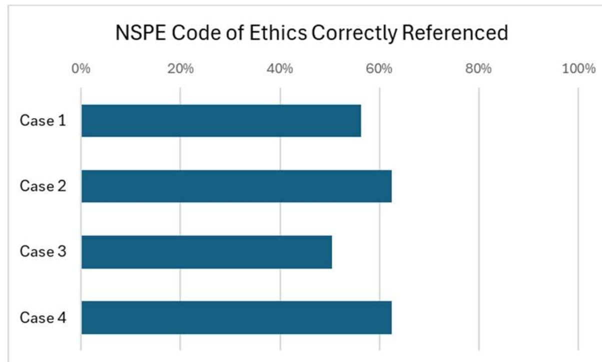

Figure 3: Percentage of NSPE ethic codes correctly referenced by assigned case

Additionally, summary responses by the teams to activity worksheet Question 4 provide significant insight into the interactive experience of the students, which have been organized in Table 1. Question 4 states: "Describe how the Engineering Ethics Coach (AI chatbot) assisted with completing your activity. Specifically, how did it benefit your understanding?"

Table 1. Team responses to Question 4 describing how the Engineering Ethics Coach assisted them.

Case	Team	Student Response
Case 1	Team 1	Students reported that the Engineering Ethics Coach "*helped guide our thinking*" and encouraged them to better evaluate risks and sustainability considerations beyond their initial perspectives.
	Team 2	Students noted that the chatbot "*critiqued our responses*" and highlighted missing aspects, which improved their ethical analysis and strengthened their connections to the NSPE Code of Ethics.
Case 2	Team 3	The team appreciated that the chatbot "*confirmed our correctness*" when appropriate and challenged them to consider additional ethical concerns, improving their team collaboration.
	Team 4	Students indicated that the chatbot interaction "*allowed us to think more critically*," leading to deeper discussion and reflection during case study evaluation.
Case 3	Team 5	This team highlighted the chatbot's role in "*broadening our perspective*," prompting them to reassess initial assumptions and apply ethical reasoning more thoroughly.
	Team 6	Students valued the chatbot's ability to "*suggest missing ethical issues*" and guide them without directly giving answers, reinforcing independent ethical thinking.
Case 4	Team 7	The team reflected that the chatbot "*brought up aspects we had not thought about*," supporting richer discussion and encouraging attention to public welfare implications.
	Team 8	Students stated that the chatbot "*helped us refine our application of ethical codes*" and facilitated more structured, team-based decision-making.

Thematic Analysis of Student Engagement and Decision-Making

The thematic analysis aimed to uncover patterns in how students engaged with ethical dilemmas, leveraging the AI chatbot as a decision-making tool, and to evaluate the integration of ethics into engineering economic analyses. This approach was essential for identifying strengths, challenges, and opportunities to enhance student learning and better prepare them for the complexities of professional practice. Five dimensions emerged: (1) ethical reasoning and decision-making; (2) chatbot interactions; (3) team dynamics; (4) team dynamics; and (5) reflections on learning outcomes.

Ethical Reasoning and Decision-Making

Students consistently demonstrated a strong understanding of the NSPE Code of Ethics, integrating these principles into their analyses and recommendations. For instance, in Case 2: Public Welfare at What Cost?, several teams referenced Fundamental Canon 1, which emphasizes holding paramount the safety, health, and welfare of the public. This principle guided their rejection of cost-saving measures that posed significant safety risks. Similarly, in Case 3: Climate Change Induced Conditions, teams aligned their recommendations with Professional Obligation 2.d, advocating for environmentally sustainable solutions even when such options required greater initial investments. These examples illustrate how students effectively connected ethical standards with real-world engineering challenges.

Teams also engaged deeply with trade-offs between ethical principles and economic considerations. In Case 1: Avoiding Rolling Blackouts, teams prioritized immediate financial feasibility and service reliability, citing societal reliance on uninterrupted energy. Conversely, in Case 3, teams focused on the long-term societal benefits of sustainability, emphasizing the ethical imperative to minimize environmental harm. Teams that engaged more thoroughly with ethical principles often produced balanced and forward-looking recommendations, demonstrating the value of integrating ethics into economic decision-making.

Chatbot Interactions

The chatbot played a critical role in shaping team discussions and recommendations. Most teams utilized the chatbot to explore ethical dilemmas, validate their decisions, and identify relevant ethical principles. For example, in Case 4: Drinking Water Quality, Team 7 used the chatbot to assess health risks associated with cost-effective filtration methods, ensuring their solution balanced public health with financial constraints. Similarly, Team 3 in Case 2 relied on iterative questions to refine their rejection of unsafe but economical solutions.

Despite its overall effectiveness, one team faced challenges due to an improperly reset chatbot session. As the chatbot remained aligned with the demonstration case rather than their assigned scenario, its guidance was less relevant. However, this issue was isolated and primarily procedural, underscoring the importance of proper pre-activity setup. Other teams praised the chatbot for encouraging deeper ethical exploration, with students frequently noting its value in prompting critical thinking and expanding their analyses.

Team Dynamics

Collaboration emerged as a key factor in the success of the exercise. Teams consistently emphasized the importance of group discussions in refining their analyses and decisions. For example, Team 8 in Case 4 highlighted how internal debates helped them prioritize public health over cost considerations, leading to a more ethically robust recommendation. Similarly, Team 1 in Case 1 reported that collaborative brainstorming sessions clarified their understanding of cost-benefit analyses and ethical trade-offs. These examples demonstrate the exercise’s ability to foster meaningful teamwork and collective reasoning.

Reflections on Learning Outcomes

Students expressed significant learning gains from the exercise, particularly in understanding the intersection of ethics and engineering economics. Many noted that the activity broadened their perspective on how ethical principles influence decision-making in professional practice. One student reflected, "*The chatbot's responses made me think about factors I hadn't considered, like how this decision would affect public trust*." Another remarked, "*I realized how often ethical considerations are overlooked in favor of cost. This activity taught me how to balance both*."

Suggestions for improvement included tailoring the chatbot's personality to provide more critical feedback and extending the time allocated for discussions. Students also recommended incorporating a post-activity debrief to consolidate learning outcomes and address unresolved questions. These insights align with broader opportunities to enhance the exercise's educational value.

Summary Discussion

The thematic analysis highlights the exercise's success in fostering ethical reasoning, collaborative decision-making, and critical engagement with engineering economic challenges. While isolated technical issues highlighted areas for procedural improvement, the overall feedback underscores the value of integrating AI tools and ethical frameworks into engineering education. Tailoring chatbot interactions, enhancing pre-activity training, and allocating more time for reflection could further strengthen this innovative approach, preparing students for the complexities of professional practice.

3.2 Course Evaluation Supplemental Analysis

To evaluate the impact of incorporating an AI chatbot into ethical decision-making exercises, students were surveyed at the end of the semester regarding their perceptions and experiences. The survey included a series of questions that assessed the chatbot activity's engagement, relevance, and effectiveness in fostering understanding of ethical and economic considerations. Additionally, students were asked to reflect on the role of AI tools in engineering education and their prior familiarity with such technologies. The responses provide valuable insights into how students perceived the activity and the chatbot's utility in preparing them for professional engineering practice. This section presents a detailed analysis of the survey results, highlighting key themes, areas of success, and opportunities for refinement in future implementations of AI tools in the engineering economy curriculum. The findings contribute to a broader understanding of the pedagogical value of interactive AI tools in engineering education.

Thirteen questions were presented to the students when completing their end of semester course assessment as a supplemental survey. The survey was completed individually by the students two weeks after the in-class exercise, and after the completion of the self-reflection assignment. Responses to the questions are presented below in Figures 4 through 15.

Student Engagement and Ethical Understanding (Questions 1-4)

Survey responses indicated strong student engagement with the Engineering Ethics Coach activity. As shown in Figure 4 (Q1), most students agreed that the chatbot enhanced their participation and attentiveness, suggesting that the interactive format encouraged more active involvement during the case study discussions. Students also reported that the chatbot helped them engage more directly with ethical dilemmas, Figure 5 (Q2), by prompting them to think critically about trade-offs and consequences in real-world contexts. In Figure 6 (Q3), students agreed that the activity made ethical considerations feel more relevant to engineering practice, underscoring the effectiveness of situating professional ethics within applied decision-making scenarios. Finally, Figure 7 (Q4) indicates that the chatbot helped students better understand the connection between ethical and economic dimensions of engineering work—reinforcing the value of integrating ethics instruction into Engineering Economy courses.

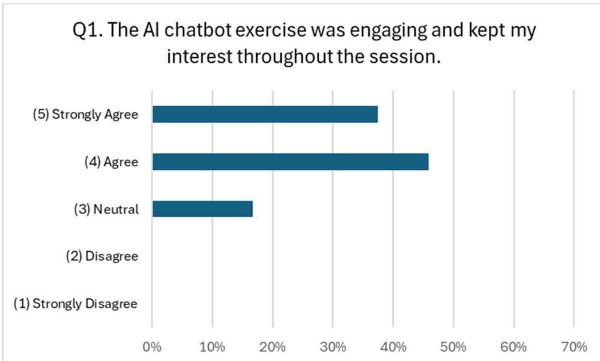

Figure 4: Student perceptions of engagement during the AI chatbot exercise (Question 1).

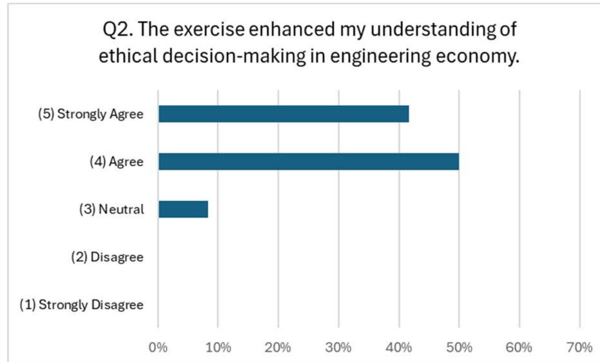

Figure 5: Student perceptions of ethical understanding gained from the exercise (Question 2).

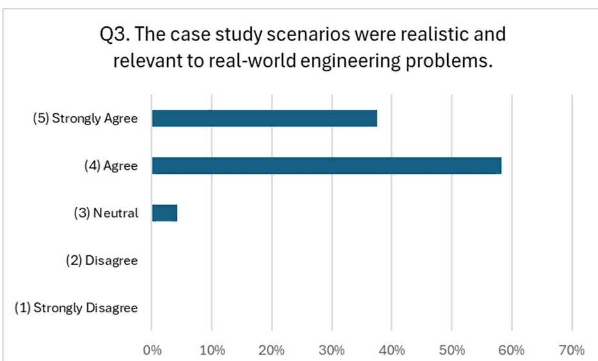

Figure 6: Student perceptions of scenario realism and relevance (Question 3).

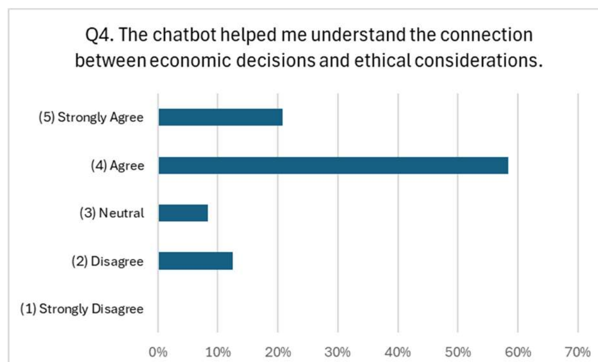

Figure 7: Student perceptions of the link between economic and ethical decision-making (Question 4).

Critical Thinking and Decision-Making Support (Questions 5-8)

Students largely agreed that the chatbot supported critical thinking during ethical evaluations, as shown in Figure 8 (Q5), and encouraged them to reconsider initial assumptions and explore alternative perspectives, Figure 9 (Q6). These responses suggest that the Engineering Ethics Coach facilitated deeper ethical reflection and helped students move beyond surface-level analysis. Students also reported that the chatbot contributed to more balanced consideration of ethical and economic trade-offs during team discussions, Figure 10 (Q7). This indicates that the AI tool not only supported individual reasoning but also enhanced group dialogue around complex dilemmas. Finally, students expressed increased confidence in applying decision-making frameworks in economic analysis after the activity, as reflected in Figure 11 (Q8). Collectively, these results point to the chatbot's effectiveness in reinforcing structured thinking and ethical awareness within the Engineering Economy context.

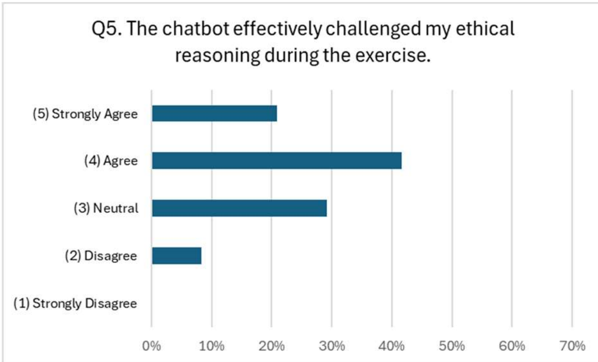

Figure 8: Student perceptions of critical thinking support provided by the AI chatbot (Question 5).

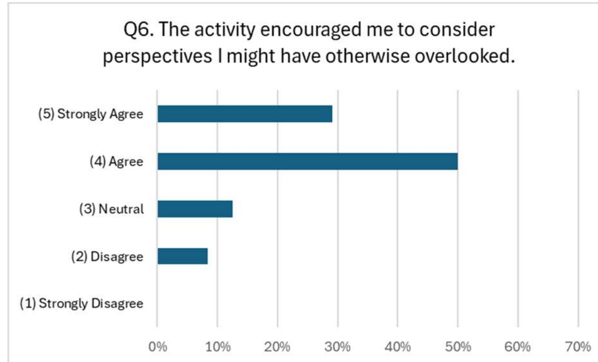

Figure 9: Student reflections on reconsidering initial assumptions (Question 6).

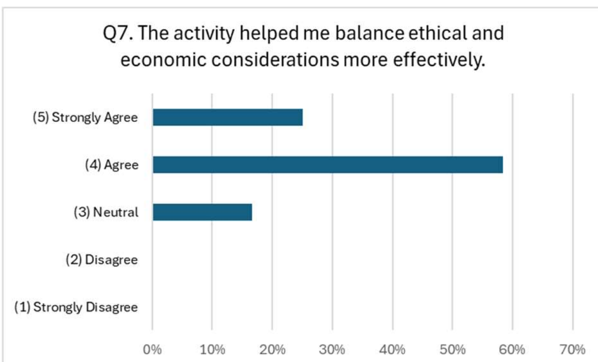

Figure 10: Student perceptions of balancing ethical and economic factors (Question 7).

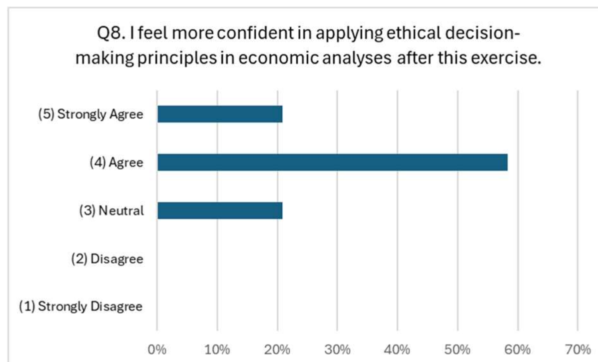

Figure 11: Student confidence in ethical economic decision-making after the activity (Question 8).

Prior AI Familiarity and Student Preferences (Questions 9–12)

The final set of survey responses examined students' perceptions of the chatbot-supported activity, its impact on ethical reasoning, prior familiarity with AI tools, and preferences for future use. Figure 12 (Q9) shows that most students found the activity insightful and engaging, affirming the instructional value of the Engineering Ethics Coach as an interactive tool that fosters motivation and deeper reflection. In Figure 13 (Q10), the majority reported that the experience helped prepare them to handle ethical dilemmas in professional contexts, suggesting meaningful growth in applied ethics within an economic decision-making framework. Figure 14 (Q11) indicates that most participants had limited or no prior experience with AI or chatbots, highlighting the novelty of the learning approach. Figure 15 (Q12) demonstrates strong support for integrating AI tools into other parts of the course, with students emphasizing the importance of alignment with instructional goals and ethical outcomes.

Collectively, these findings reflect a positive outlook on the role of thoughtfully designed AI tools in engineering education. Even among students with minimal prior exposure, the Engineering Ethics Coach was recognized as a valuable resource that supported ethical development and enriched the learning experience.

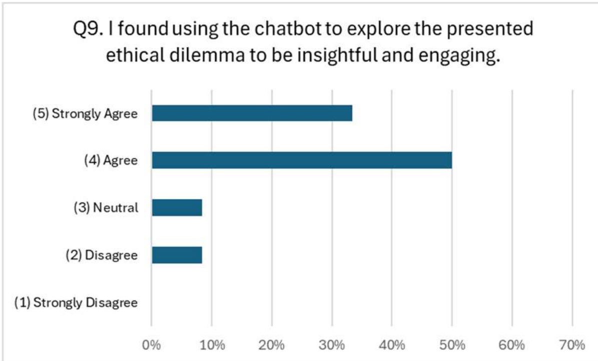

Figure 12: Student perceptions of the chatbot's engagement and insightfulness (Question 9).

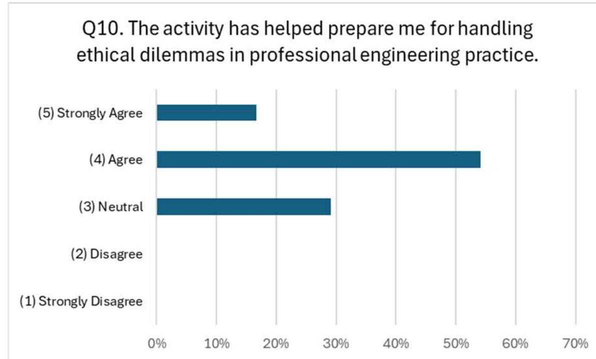

Figure 13: Student confidence in handling ethical dilemmas after exercise (Question 10).

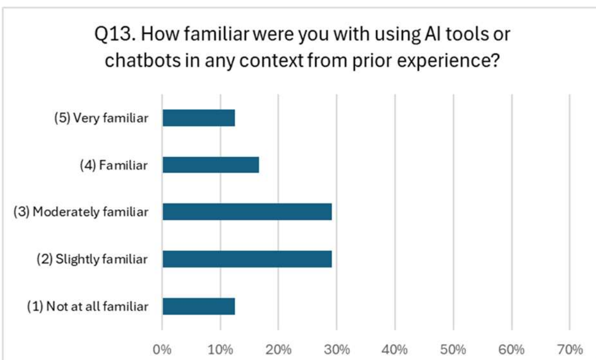

Figure 14: Student familiarity with AI tools prior to the activity (Question 11).

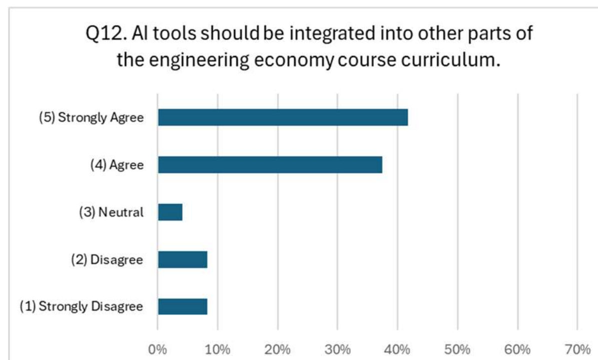

Figure 15: Student preferences for integrating AI into the course curriculum (Question 12).

Thematic Analysis Discussion

The activity successfully engaged students in ethical decision-making, as evidenced by the abundance of positive feedback. While a few students noted technical challenges, these were not a widespread concern and did not significantly detract from the overall value of the experience. Pre-activity preparation could also play a crucial role in addressing these challenges. Providing students with a clear overview of the chatbot's functionality, limitations, and effective usage strategies would help mitigate technical hurdles and enable more meaningful engagement.

The potential for enhanced engagement is supported by findings from Question 13 of the survey, which asked students if this exercise was their first time engaging with an AI chatbot in an educational activity. A majority of 13 students (54.2%) indicated that this was their first experience working with an AI chatbot on an assignment. Another 8 students (33.3%) reported previous self-directed experience using AI, often for tasks like learning about unfamiliar topics, solving problems, or checking answers, with varying levels of success. Finally, 3 students (12.5%) indicated prior use of AI as part of a structured or unstructured class activity. These results suggest that while some students were already familiar with AI tools, for many, this activity served as an introduction to the educational applications of such technology.

A notable opportunity lies in refining the personality and interaction style of the chatbot to influence how students engage with it. By tailoring the chatbot's approach to be more cooperative or more critical, educators could create distinct learning experiences that better align with the activity's objectives. For example, a cooperative chatbot might focus on reinforcing students' reasoning, providing guidance, and validating their decisions, thereby fostering confidence in applying ethical principles.

3.3 Cohort Comparison: Traditional vs. AI Chatbot

To evaluate learning outcomes across cohorts, student responses from Fall 2024 (AI chatbot-enhanced, n = 24) were compared with those from Fall 2023 (traditional method, n = 22). Both groups completed an identical ethics essay question as part of their final exam. Responses were evaluated using a four-category rubric developed by the course instructor, focusing on: (1) recognition of ethical guidelines, (2) understanding of professional responsibility, (3) identification of actionable responses, and (4) articulation of the appropriate ethical response. All essays were independently scored by two raters (RS and ES) using a well-defined rubric, with full agreement reached on the final scores (see Appendix A for rubric details).

Final Exam Ethics Essay Question: *"Suppose you are an engineer working in a private engineering firm and you are asked to sign documents verifying information that you believe is not true. You like your work and your colleagues in the firm, and your family depends on your income. What criteria can you use to guide your decision regarding this issue? What actions would you take?"*

To determine whether the treatment, the application of the Engineering Ethics Coach with the cohort in 2024, produced statistically significant differences, two-sample t-tests assuming unequal variances were conducted. The null hypothesis for each test assumed no difference in mean scores between the cohorts. As shown in Table 2, all four categories showed statistically significant improvements in the AI-supported cohort, with p-values well below conventional significance thresholds.

Table 2. Summary comparison of final exam essay scores between Fall 2023 and Fall 2024 (treatment) cohorts across four rubric categories. All differences are statistically significant.

	2023		2024		t-test
Category	Mean	SD	Mean	SD	(significance)
1 Recognition	2.48	1.12	3.70	1.05	3.71**
2 Responsibility	2.71	1.06	4.37	0.77	5.89****
3 Action	1.67	0.86	3.52	1.38	5.41***
4 Response	3.05	1.07	4.83	0.49	6.96****

significance level: $^{**}p < 0.001$, $^{***}p < 0.0001$, $^{****}p < 0.00001$

In Category 1: Recognition of Ethics Guidelines, student responses were evaluated based on their ability to recognize and apply ethical guidelines to the case scenario. Ideally, students would explicitly reference the NSPE Code of Ethics, including relevant Fundamental Canons, Rules of Practice, or Professional Obligations, and clearly explain how these principles apply to the ethical dilemma at hand. As shown in Figure 16, 66.7% of students in the Fall 2024 AI-supported cohort scored a 4 or 5, indicating a strong ability to identify appropriate ethical standards and justify their relevance. In contrast, only 4.5% of Fall 2023 students achieved this level of performance. Many responses from the traditional cohort made vague or generalized statements about "ethics" without specific reference to professional codes. By contrast, students using the Engineering Ethics Coach were more likely to name specific canons and relate them directly to the engineer's obligations in the scenario.

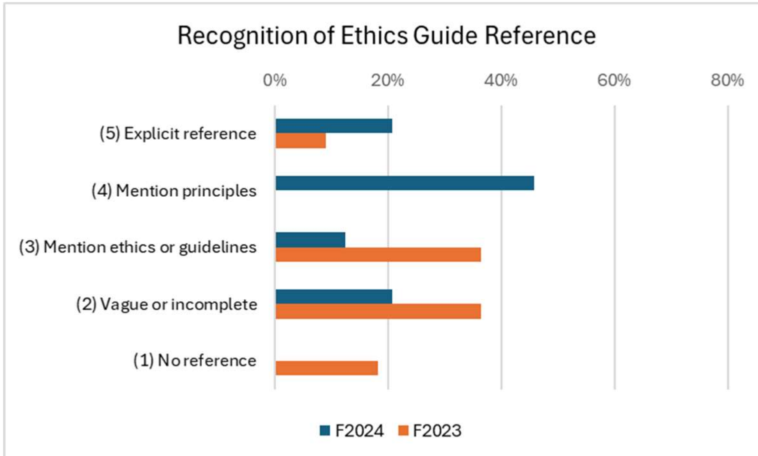

Figure 16: Distribution of student scores for Category 1: Recognition of Ethics Guidelines.

In Category 2: Responsibility as a Professional Engineer, student responses were evaluated based on how well they identified their obligations as a professional engineer. Ideally, students would present a comprehensive discussion of the engineer's responsibility to uphold public safety, honesty, and professional integrity, recognizing these duties as paramount. As shown in Figure 17, 83.3% of students in the Fall 2024 cohort scored a 4 or 5, compared to only 18.2% in Fall 2023. Responses from the traditional group often described responsibility in vague terms or focused narrowly on compliance, whereas AI-supported students were more likely to articulate the engineer's broader ethical duty to protect the public and act with integrity, even under pressure.

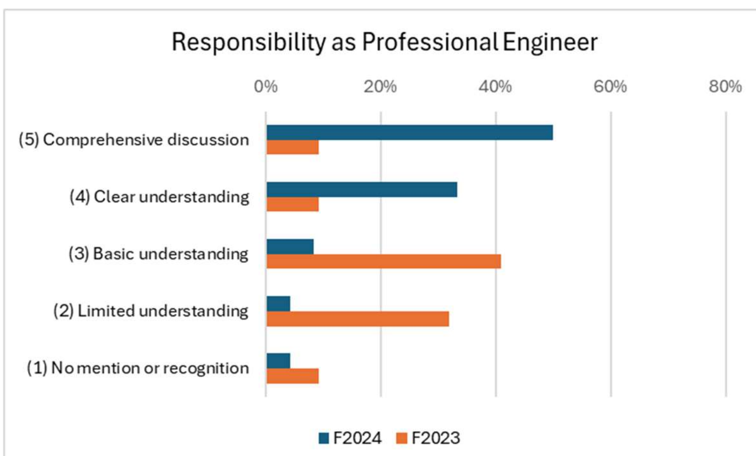

Figure 17: Distribution of student scores for Category 2: Responsibility as Professional Engineer.

In Category 3: Actions to Help Address the Falsehood, this category proved more difficult for both cohorts, as reflected by generally lower performance levels. However, as shown in Figure 18, the AI-supported cohort demonstrated a substantially stronger ability to identify and articulate ethically grounded action steps. Specifically, 54.2% of Fall 2024 students scored a 4 or 5, compared to only 4.5% in Fall 2023, where no students achieved a top score. Responses from the traditional cohort tended to offer vague or general intentions—such as "report the issue" or "tell someone in charge"—without a clear path of action. In contrast, students who used the Engineering Ethics Coach more frequently proposed sequenced and specific responses aligned with the NSPE Code of Ethics, including documentation, internal reporting channels, and appropriate escalation procedures.

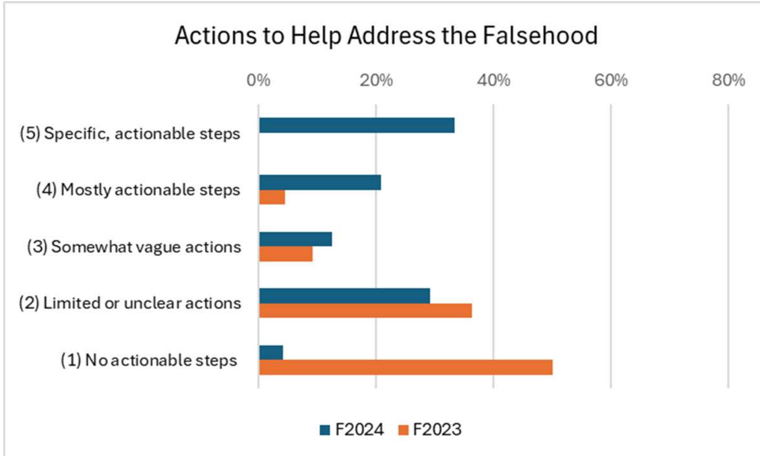

Figure 18: Distribution of student scores for Category 3: Actions to Help Address Falsehood.

In Category 4: Response the Engineer Should Take, the student responses were evaluated with respect to the action or response the engineer should take in the presented dilemma. Ideally, students would provide a clear and ethical course of action—such as refusing to sign inaccurate documents while explaining their reasoning to superiors and offering alternative, ethically sound solutions—demonstrating alignment with both professional standards and personal integrity. As shown in Figure 19, 95.8% of Fall 2024 students scored a 4 or 5, indicating strong performance in articulating a definitive and ethically grounded response. In contrast, only 31.8% of students in the Fall 2023 cohort reached this level, with many providing vague, noncommittal, or incomplete recommendations. Students supported by the Engineering Ethics Coach not only recognized the correct course of action but also expressed it with greater confidence and professional clarity.

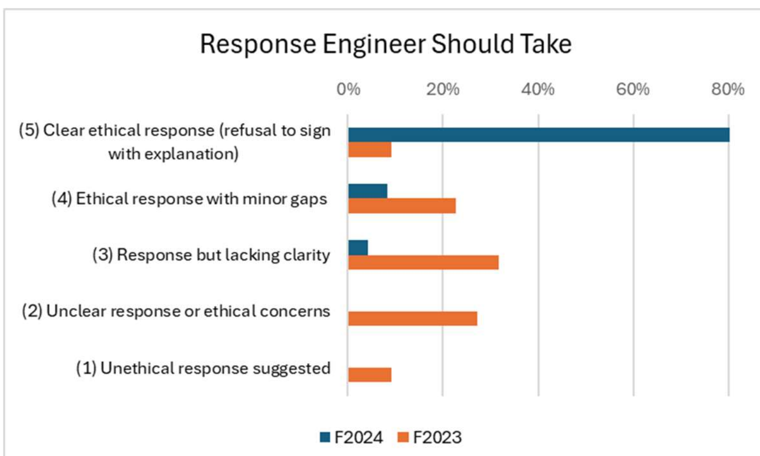

Figure 19: Distribution of student scores for Category 4: Response Engineer Should Take.

Taken together, the statistically significant results across all four categories support the effectiveness of the AI-supported instructional approach. Students who used the Engineering Ethics Coach outperformed the traditional cohort in recognizing ethical standards, understanding professional responsibilities, proposing corrective actions, and selecting appropriate responses. The consistently significant differences indicate that the chatbot enhanced not only ethical awareness but also students' ability to apply ethical principles in practical, decision-making contexts. These findings reinforce the value of AI tools in enhancing ethical reasoning and decision-making within Engineering Economy education.

4. Conclusion

This study highlights the instructional potential of the Engineering Ethics Coach—an AI chatbot designed to support ethical reasoning in Engineering Economy. By guiding students through structured case-based exercises grounded in the NSPE Code of Ethics, the chatbot promoted deeper critical thinking, collaborative discussion, and more confident engagement with complex ethical dilemmas. Compared to students taught using traditional methods, those who interacted with the chatbot demonstrated stronger engagement and a higher frequency of accurate and relevant ethical code references.

The results provide valuable insights into the study's research questions. First, the chatbot enhanced student engagement by fostering real-time interaction and encouraging deeper exploration of trade-offs in ethical decision-making. Second, students using the tool exhibited improved understanding of professional responsibility and demonstrated stronger application of ethical principles to engineering scenarios. Third, comparative analysis with a prior cohort revealed that AI-supported students displayed greater depth in reasoning, more specific corrective actions, and clearer articulation of appropriate ethical responses.

Thematic analysis further revealed several benefits: improved familiarity with the NSPE Code of Ethics, strengthened team dynamics, and greater awareness of ethical and economic trade-offs. Students appreciated the chatbot's ability to provide guided feedback, support reflection, and broaden their perspectives on professional dilemmas. While the intervention was largely successful, opportunities remain to enhance the experience—particularly through improved technical reliability, refinements in the chatbot's critique logic, and more structured onboarding.

Building on these results, future work will explore:

- How learning environments, team composition, and case complexity influence ethical engagement with AI tools.
- Ways to refine the chatbot's interaction style to support ethical reflection and challenge assumptions.
- Curriculum integration strategies that preserve academic rigor while incorporating AI-based support.

By advancing these areas, this research aims to optimize the role of AI in ethics education, equipping future engineers with the judgment, adaptability, and professional integrity needed to navigate complex, real-world decisions.

Engineering Economy offers a unique platform for introducing students to the ethical dimensions of professional practice, as it naturally integrates technical, financial, and societal trade-offs. Embedding tools like the Engineering Ethics Coach in such foundational courses not only supports students' ethical development early in their education but also models how AI can be responsibly leveraged to enhance critical thinking. This approach may be extended to other contexts—such as design courses, sustainability, or capstone projects—where ethics and decision-making intersect in meaningful ways.

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Appendix A

Scoring Rubric for the Final Exam Ethics Question Essay

1. Recognition of Ethics Guide (5 points)
   - 5 points: Explicit reference to the NSPE Engineering Ethics Reference Guide or relevant ethical codes, with a clear explanation of their application to the scenario.
   - 4 points: Mention of the ethics guide or principles, with minor gaps in application or understanding.
   - 3 points: General mention of ethics or ethical guidelines but without specifying the NSPE guide or connecting it effectively to the scenario.
   - 2 points: Vague or incomplete recognition of ethics, lacking specificity or relevance.
   - 1 point: No reference to ethics guides or principles.

2. Responsibility as a Professional Engineer (5 points)
   - 5 points: Comprehensive discussion of the engineer's responsibility to uphold public safety, honesty, and professional integrity, emphasizing their paramount importance.
   - 4 points: Clear understanding of professional responsibilities but lacking depth or specificity.
   - 3 points: Basic understanding of responsibilities, with minor inaccuracies or omissions.
   - 2 points: Limited understanding, with significant gaps in knowledge or application.
   - 1 point: No mention or recognition of professional responsibility.

3. Actions to Help Address the Falsehood (5 points)
   - 5 points: Specific, actionable steps to address the falsehood (e.g., gathering evidence, consulting with supervisors or legal counsel, refusing to sign), demonstrating initiative and adherence to ethical principles.
   - 4 points: Mostly actionable steps, but with some gaps or lack of detail.
   - 3 points: General or somewhat vague actions that could address the falsehood but lack clarity.
   - 2 points: Limited or unclear actions, with significant omissions in addressing the falsehood.
   - 1 point: No actionable steps presented.

4. Response They Should Take (5 points)
   - 5 points: Clear and ethical response (e.g., refusal to sign documents while explaining reasoning to superiors and offering alternative solutions), aligning with professional standards and personal integrity.
   - 4 points: Ethical response provided but with minor gaps in alignment with professional standards.
   - 3 points: Response provided but lacking clarity, detail, or strong ethical alignment.
   - 2 points: Incomplete or unclear response, with questionable ethical considerations.
   - 1 point: No response provided, or unethical response suggested.

Appendix B

Case 1: NSPE Case No. 21-07, Public Safety, Health & Welfare: Avoiding Rolling Blackouts

Facts:

Engineer A works for an organization that for years has operated a fossil-fueled co-generation facility primarily to supply thermal energy for process needs. The facility has the capability to produce electric energy when thermal energy needs are satisfied, in fact, there are times when a significant portion of the organization's electric energy is supplied by the co-generation facility. The generator is approaching the end of its useful life and will require a substantial investment to remain operational.

Recently, stakeholders have expressed interest in reducing the organization's carbon footprint, and these stakeholders suggest that the facility eliminate the generator and replace it with solar panels. After careful study of the facility electric load profile and the capability of the proposed solar energy system, Engineer A is satisfied that under normal conditions, the system of solar panels can supply electric energy equivalent to that provided by the existing generator. Capital constraints prevent the organization from installing a system of batteries to store energy for use at night or in bad weather, but the cost of installing the solar panels is essentially the same as the cost to rebuild the generator.

When discussing the analysis of the electric load profile with a representative of the local electric utility, Engineer A learns that the utility resource planners reviewed their current generation mix and believe that during extreme weather events, they may be forced to institute rolling outages to keep system generating facilities on-line.

Engineer A is preparing a report that will be presented to the board to consider the new solar project, and is convinced that the solar project, when considered in isolation, is viable and will satisfy those stakeholders interested in reducing the organization's carbon footprint. Engineer A also realizes that a move to solar production without storage may stress the local utility generation mix even more, increasing the likelihood of rolling blackouts.

Questions:

1. Should Engineer A include information about the utility generation mix and rolling blackouts in the report to the board?
2. Should Engineer A include information about the cost of battery storage and the potential consequences of not having battery storage?

Case 2: NSPE Case No. 21-11, Public Safety, Health & Welfare: Public Welfare at What Cost?

Facts:

A consultant recently determined the existing water main in Shadyvale is generally in good condition but extremely old. Further, the water main is no longer large enough for all the properties served. The cost to replace it is an unaffordable $750,000. The State DOT is planning a highway reconstruction project in Shadyvale. Engineer W is the senior DOT engineer responsible for this project Engineer W delegates the project to Engineer Intern D, who is about to sit for the PE exam. State DOT policy unambiguously requires that only unavoidable utility conflicts will be paid for as part of highway projects, and that other utility work is to be considered as a betterment that must be paid for by the local municipality. Engineer Intern D initiates the design layout for the Shadyvale DOT project to avoid conflicts with the existing utilities, including separation of a new closed drainage system from the old water main. During design development review, Engineer W conveys to Engineer Intern D in an indirect way that the design should be revised so that the old water main is impacted. In that case, the cost to Shadyvale would be only the difference in price between the existing size of the water main and the proposed larger size, rather than the entire water main replacement cost. As a result, Shadyvale would pay an affordable $50,000 for the water main upgrade, an amount they can afford. Engineer W tells Engineer Intern D, "I'll sign off on it."

Questions:

1. Would it be ethical for Engineer Intern D to revise the design so that the old water main is impacted by the DOT project?
2. Would it be unethical for Engineer W to sign off on the design where the old water main is impacted by the DOT project?

Case 3: NSPE Case No. 21-02, Public Safety, Health & Welfare: Climate Change Induced Conditions

Facts:

Engineer A is a consulting engineer representing Client B, a developer who is proposing to develop a health care facility that requires a significant upgrade to the property's access road that crosses a tidal saltmarsh. Engineer A's scope includes design and local permitting of the roadway, including an upgrade of the tidal crossing from a small culvert to a small bridge, increasing its hydraulic capacity. Local development regulations require designing for a 25-year fresh-water storm, and assume that future weather conditions will be consistent with updated historical data. The local development regulations and national design codes and standards have not yet been updated to reflect changing conditions and weather patterns, including effects of sea level rise and changes in precipitation intensities and recurrence intervals effected by on-going climate change. It is Engineer A's judgment, based on hydraulic evaluation procedures presented at a recent transportation agency conference, that the proposed project may result in some upstream homes becoming uninhabitable a decade or more earlier than would otherwise be the case. Engineer A proposes a complex and costly hydrologic and hydraulic analysis by a specialized subconsultant to predict the extent to which sea level rise and the increased hydraulic capacity of the tidal crossing will result in flood damage to a neighborhood of twenty upstream homes during future high tides and storm surges, anticipating this to be a difficult question to answer in the project's public hearings. Client B directs Engineer A to proceed without the costly analysis unless and until such an analysis is requested by the applicable regulatory authorities.

Questions:

1. Does Engineer A have an ethical obligation to address or evaluate the impacts of a project on public health, safety, and welfare with respect to climate change induced conditions that have not yet occurred?
2. In this set of circumstances, what are Engineer A's reasonable courses of action with respect to engineering ethics?

Case 4: NSPE Case No. 20-04, Public Safety, Health & Welfare: Drinking Water Quality

Facts:

Engineer A is a professional engineer who serves as the superintendent and chief engineer for the Metropolitan Water Commission (MWC). In order to reduce municipal expenditures and lower water rates, the MWC has been considering changing its water supply source from purchasing water from remote reservoirs from another regional authority to using the local river as the MWC's source. Engineer B, a consulting engineer retained by the MWC charged with evaluating water treatment needs for the change in water source, provided a report to Engineer A recommending extensive capital investments and a three-year timeline for further evaluation of water quality, design, and construction of improvements. The improvements are needed prior to the change in water source to ensure that sufficient corrosion control is provided so that old service pipes in the MWC service area don't leach lead at levels in excess of drinking water standards. Both Engineer A and Engineer B met with the MWC at a meeting sparsely attended by the public and recommended that the change in water sources be substantially delayed until improvements could be completed. Despite those recommendations, the MWC voted to proceed simultaneously with the accelerated evaluation and design of needed water treatment improvements and the change in water source.

Questions:

1. What are the ethical obligations of Engineer A and Engineer B in this circumstance?
2. What should Engineer A and Engineer B do?