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Integrating AI in Technical Courses: A Structured Approach to Developing Engineering Problem-Solving Skills

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ABSTRACT

The rapid advancement of artificial intelligence is fundamentally transforming engineering education. This paper presents a systematic pedagogical framework for integrating AI tools into technical engineering courses across six engineering and information technology courses at a southeastern university. The framework employs a three-phase scaffolded model; instructor-provided prompts, guided prompt modification, and fully independent prompt crafting delivered through 15 graded discussion assignments per course. Students documented each interaction using a standardized format: AI and Version Used, Prompt Used, AI Response, and Student Response and Comments. Peer evaluation across all 15 discussions reinforced critical comparison of AI outputs. End-of-semester surveys (n=45 open-ended, n=87 Likert) indicate improvements in students' ability to critically evaluate AI-generated content, construct effective prompts, and apply AI tools to discipline-specific challenges. Key themes from open-ended responses include over-reliance concerns, accuracy verification practices, and AI literacy as a career skill.

INTRODUCTION

Artificial intelligence tools have become pervasive in technical and engineering workplaces, yet most engineering curricula have not systematically addressed how students should learn to use them responsibly and effectively [1], [2]. This gap creates a practical problem: AI adoption in industry accelerates while educational institutions either prohibit or ignore it. The challenge is not whether AI will be used, students already use it, but whether they are taught to use it skillfully and critically.

Prior research confirms that AI tools can enhance student learning when properly scaffolded. Zawacki-Richter et al. [3] identified a significant gap in higher education AI research focused on the learner experience. Kasneci et al. [2] outlined both the opportunities and risks of large language models for education. The present study responds directly to this literature by implementing and evaluating a structured, semester-long AI integration framework.

This paper presents findings from six engineering and information technology courses. The intervention employs graded discussion assignments that progressively develop AI literacy through three phases of increasing student autonomy. The study addresses three core learning objectives: (1) developing practical AI skills for discipline-specific problems; (2) fostering autonomous learning through guided AI-assisted exploration of complex topics; and (3) establishing ethical frameworks for appropriate AI usage in professional engineering practice.

BACKGROUND AND RELATED WORK

Research on AI in education has grown substantially. Chen, Chen, and Lin [1] reviewed AI applications in education and identified adaptive learning, intelligent tutoring, and automated assessment as primary domains. Zawacki-Richter et al. [3] conducted a systematic review of AI in higher education and found that most studies focus on institutional or systemic levels rather than student learning, underscoring the need for pedagogically grounded, course-level integration approaches such as the one described here.

The emergence of large language models such as ChatGPT has introduced new pedagogical considerations. Kasneci et al. [2] outline the potential; personalized tutoring, instant feedback, accessible explanations and risks; over-reliance, hallucinations, academic integrity concerns of LLMs in educational settings. Their analysis aligns closely with the concerns and affordances observed in the present study.

The scaffolded learning model employed here is grounded in constructivist and metacognitive frameworks. By gradually transferring responsibility for prompt crafting from instructor to student, the approach mirrors Vygotsky's zone of proximal development [4]: students are first supported within their competence and then guided to operate beyond it. This structure aligns with Bloom's revised taxonomy [5], progressing from recall and comprehension (guided phase) through application and analysis (modification phase) to evaluation and creation (independent phase).

STRATEGY FOR INTRODUCTION OF AI

Rationale for Integrating AI in Technical Courses

The primary rationale for this intervention is the growing requirement for AI fluency in the modern engineering workforce. Graduates must be proficient in leveraging AI tools for complex technical tasks while maintaining the critical judgment required to verify and correct AI outputs. Engineering education must move beyond traditional methods to prepare students for an environment where AI is a standard component of problem-solving. By integrating these tools directly into the curriculum through structured assignments, this framework ensures students develop practical AI literacy alongside foundational engineering principles.

Scaffolded Learning Approach

The framework employs a scaffolded learning model delivered through weekly graded discussion assignments. The progressive approach builds student confidence and skill through three distinct phases:

Phase 1 - Guided Interaction: Students are provided with carefully designed AI prompts and tasked with documenting and analyzing generated responses.

Phase 2 - Prompt Modification: Students assume increasing responsibility for prompt engineering, customizing queries to address specific engineering contexts and personal professional goals.

Phase 3 - Autonomous Prompt Engineering: Students independently craft prompts from given objectives, evaluate whether the AI response met their intent, and reflect critically on both the AI output and their own learning.

Ethical Considerations and Academic Integrity

Academic integrity and ethical usage are addressed through assignment design and a culture of student responsibility rather than prohibition. Three mechanisms mitigate ethical shortcuts: problem complexity (engineering problems often exceed unmodified AI capabilities); mandatory reflection (students document and critically evaluate AI outputs); and verification responsibility (students are accountable for the accuracy of their engineering work and are taught to treat AI as a study partner, not an answer key).

METHODOLOGY

Research Design

This study employed a quasi-experimental, longitudinal design to evaluate a structured AI integration framework. The unit of analysis was the individual student across a full 15-week semester. Six courses were observed, with pre-to-post changes tracked through discussion posts and end-of-semester surveys. The research questions were: (1) How does progressive AI prompt responsibility affect student engagement and critical evaluation skills? (2) What are student perceptions of AI utility, confidence, and ethical considerations after a structured semester-long integration?

Participants and Courses

The study was conducted across six courses: EGN3443 (Engineering Statistics), CEN3722 (Human-Computer Interaction), EGN3214 (Engineering Programming with Python), COP4813 (Web Applications), COP3530 (Data Structures), and COP4708 (Database Systems). Survey responses ranged from 38–45 per open-ended question across the six sections. Courses spanned both lower- and upper-division undergraduate levels, providing a range of technical backgrounds and prior AI exposure.

Discussion Assignment Structure

Each course incorporated 15 graded discussion assignments requiring the use of AI tools (e.g., ChatGPT, Claude, Gemini). Every post followed a standardized documentation format:

- **AI and Version Used:** The specific AI tool and version employed.
- **Prompt Used:** The exact prompt submitted to the AI.
- **AI Response:** The verbatim or substantially complete AI-generated response.
- **Student Response and Comments:** The student's analysis, critique, verification against course materials, and reflection on AI response quality.

In addition to their own posts, students were required to comment on at least one peer's discussion per assignment. Peer comments encouraged comparison of AI responses across different prompts and tools, and evaluation of peer reflections. A total of 6 classes × 15 discussions = 90 discussion instances were assessed. Sample prompts, rubrics, and grading criteria for each discussion are available upon request.

Three-Phase Progression of Prompt Responsibility

The 15 discussions were structured into three progressive phases designed to transfer prompt-crafting responsibility from the instructor to the student:

Phase 1: Instructor-Provided Prompts (Discussions 1–7)

For the first five to seven discussions, students were provided with fully constructed prompts. These were strategically designed based on topics that had historically caused conceptual confusion in prior course offerings. For example, in COP3530 (Data Structures), a prompt asked the AI to explain why O(2n) is mathematically reduced to O(n) in Big O notation, a concept students regularly misunderstood. In EGN3214, early prompts addressed pandas DataFrame operations. The primary goals of this phase were to establish the standard documentation format, build baseline familiarity with AI interaction, and generate a shared corpus of AI responses comparable across the class.

Phase 2: Instructor-Guided Prompt Modification (Discussions 5–12)

Beginning around Discussion 5 and extending through approximately Discussion 12, students were provided with sample prompts but explicitly encouraged to modify or replace them to match their individual learning goals. Instructions gave students broader objectives rather than specific prompts. For example, in COP4708 (Database Systems), students were asked to adapt a general database security prompt to reflect their specific career interest (e.g., cybersecurity, healthcare informatics, financial systems). This phase required students to begin thinking about what they wanted to learn from the AI rather than simply responding to pre-constructed questions.

Phase 3: Student-Directed Prompt Crafting (Discussions 10–15)

In the final phase, students were given only a broad learning objective and required to craft the prompt entirely on their own. For example, students might be directed to 'use AI to investigate a sorting algorithm relevant to large-scale data processing' without specification of which algorithm or how to frame the question. This phase also introduced an explicit self-evaluation requirement: students were required to reflect on whether the AI response adequately addressed their intended question, whether the objective was met, and what additional prompting or verification was needed. This operationalized the metacognitive goals of the framework and closed the loop between student intent and AI output.

Survey Instrument

At the end of the semester, all students completed an AI perception survey with two components. The first comprised five Likert-scale questions (1 = Strongly Disagree to 5 = Strongly Agree) assessing confidence in AI tool use, perceived utility for learning, concern about accuracy, ethical awareness, and likelihood of future use. The second comprised six open-ended questions (Questions 6–11) probing specific examples of AI-enhanced learning, concerns about AI in engineering, suggestions for future implementations, and overall reflections. Survey response rates ranged from 38–45 completed responses per open-ended question across the six courses.

Data Analysis

Likert-scale responses were analyzed using descriptive statistics (means and frequency distributions), reported separately for each course to preserve course-level variation. Open-ended responses were analyzed using inductive thematic coding: two coders independently identified recurring themes, reconciled disagreements, and grouped responses into summary categories. Representative verbatim student responses were selected to illustrate each theme. No inferential statistics were applied to the open-ended data; findings are presented as descriptive and illustrative rather than confirmatory.

EXAMPLES OF AI ASSIGNMENTS AND DISCUSSIONS

Sample Prompts Used in Weekly Assignments

To bridge the gap between abstract concepts and practical application, students received structured prompts requiring them to interface with AI as a technical partner [1]. Prompts were specific yet open-ended enough to require personal reflection. Representative examples include:

Fundamental Syntax (COP4813): "Write a single line of JavaScript code that can generate an integer between 1 and 10 and assign it to the variable random_number."

Conceptual Clarity (COP4813): "Describe the difference between defining an object and instantiating an object. Give an example in JavaScript."

Architecture and Logic (COP3530): "What are the advantages and disadvantages of using lists versus arrays?"

Security and Professional Context (COP4708): "From the viewpoint of creating a secure login system relevant to your professional interest, what are the best practices for password management?"

Structure for Critical Evaluation

The discussion format was explicitly structured to prevent passive transcription of AI outputs:

The 'My Comments' Requirement: Every AI-assisted post required a 'Student Response and Comments' section with original thought, verification, or personal research.

Mandatory Peer Review: Most assignments required replies to at least one peer, addressing both the AI explanation quality and the student's own commentary.

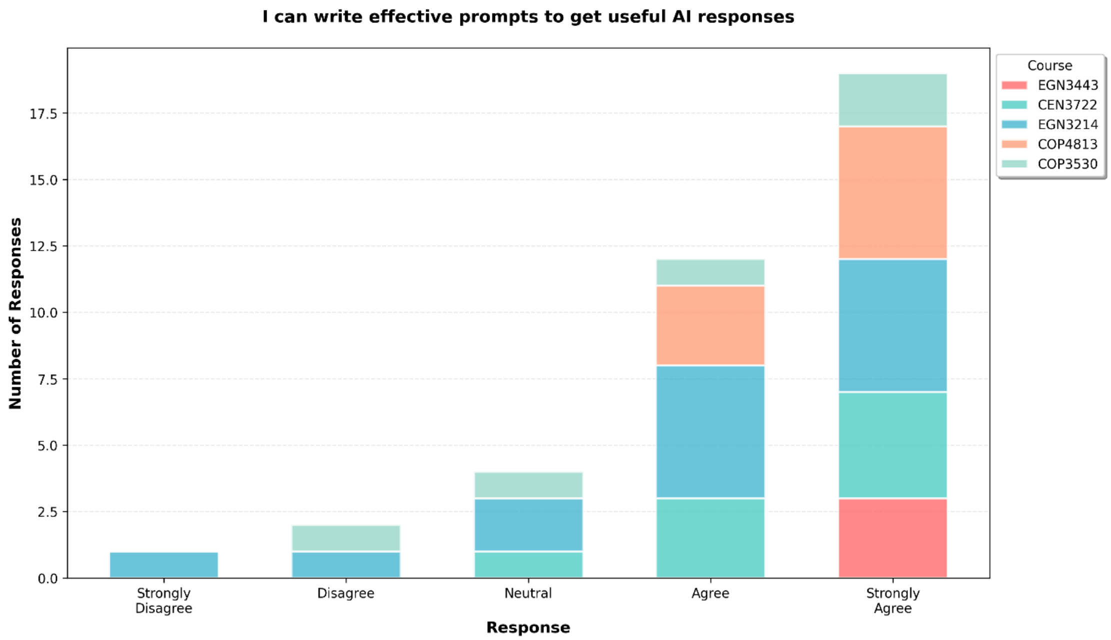
External Benchmarking: Periodic self-assessments using tools such as W3Schools quizzes allowed students to independently verify their knowledge against AI-generated content.

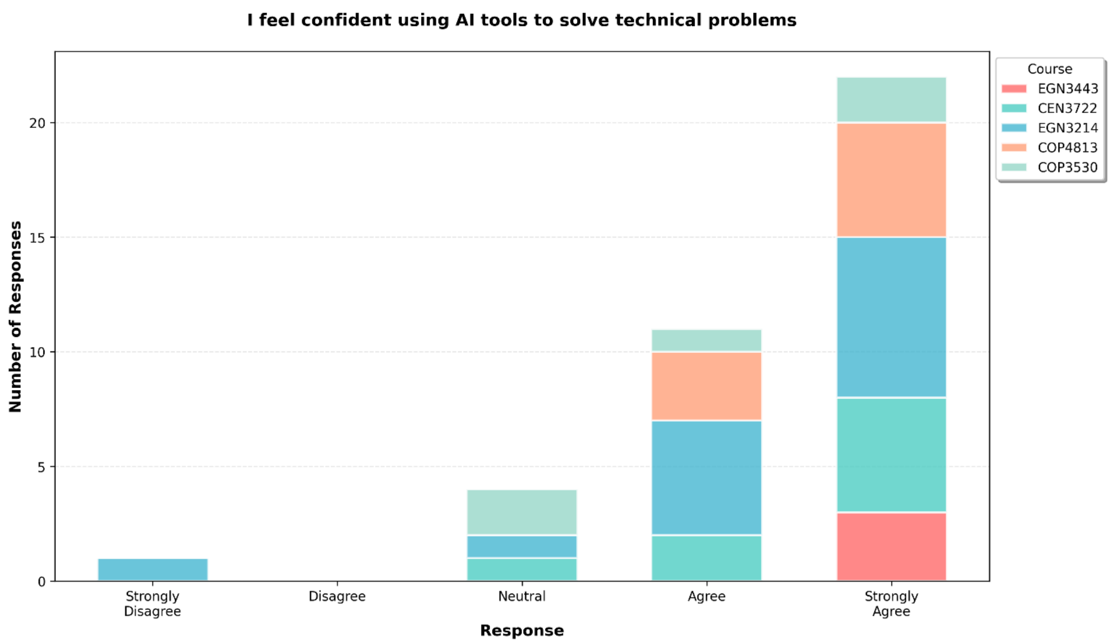
Identifying Limitations: Topics such as Big O notation required students to explain concepts that AI often fails to simplify correctly, requiring verification against course theory [1].

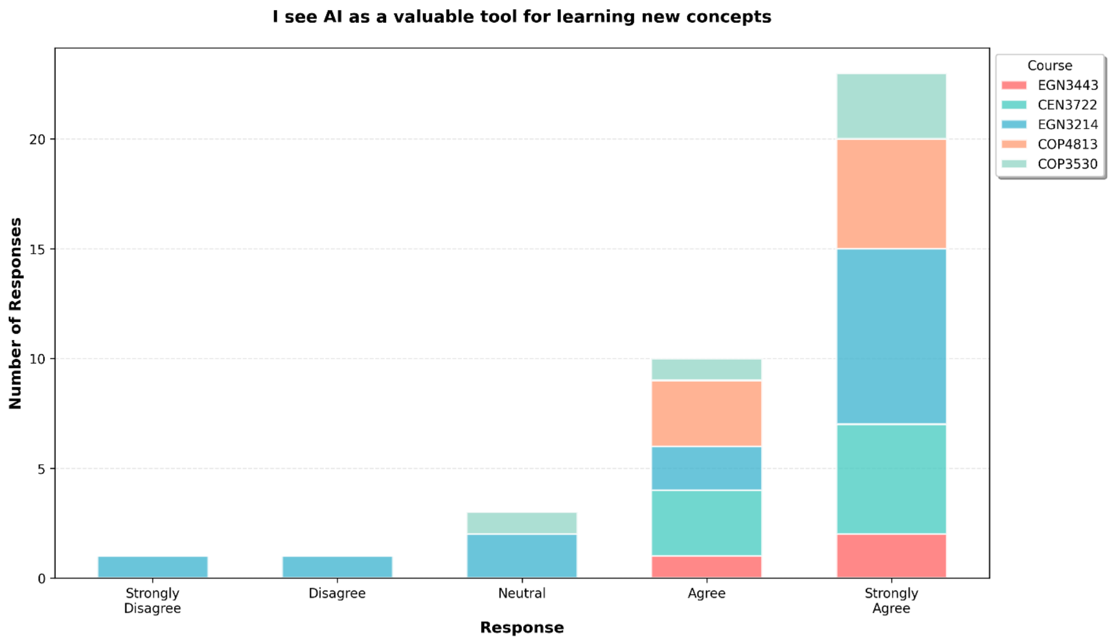
RESULTS: AI SURVEY LIKERT-SCALE QUESTIONS

Figures 1 through 25 present Likert-scale response distributions by question and course. Results are organized by survey question below.

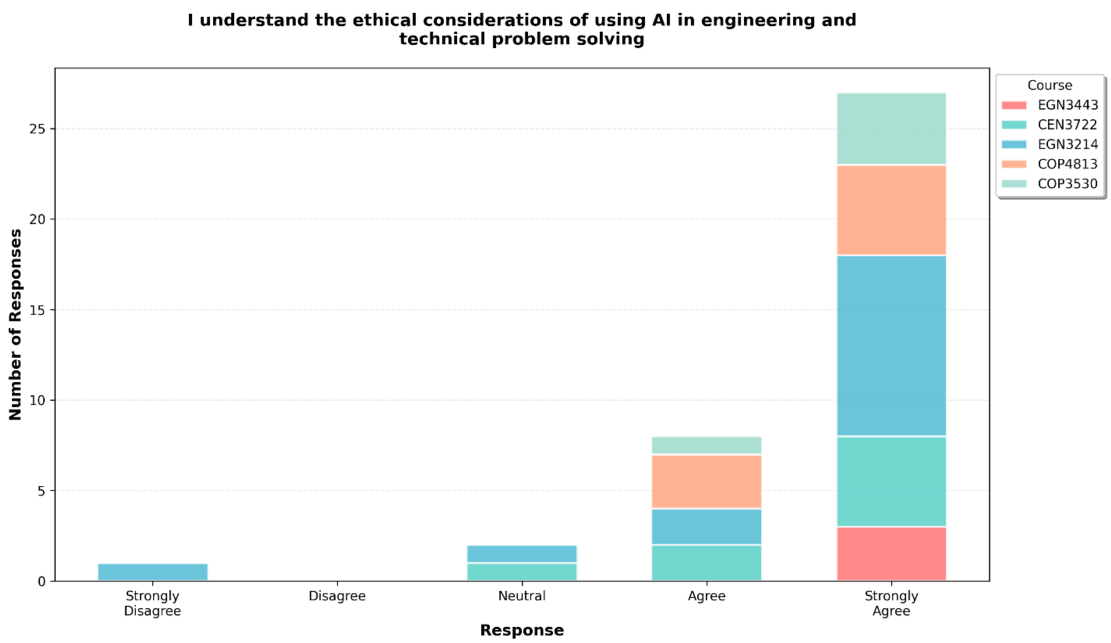
Question 1


I can write effective prompts to get useful AI responses
Number of Responses
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Response
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

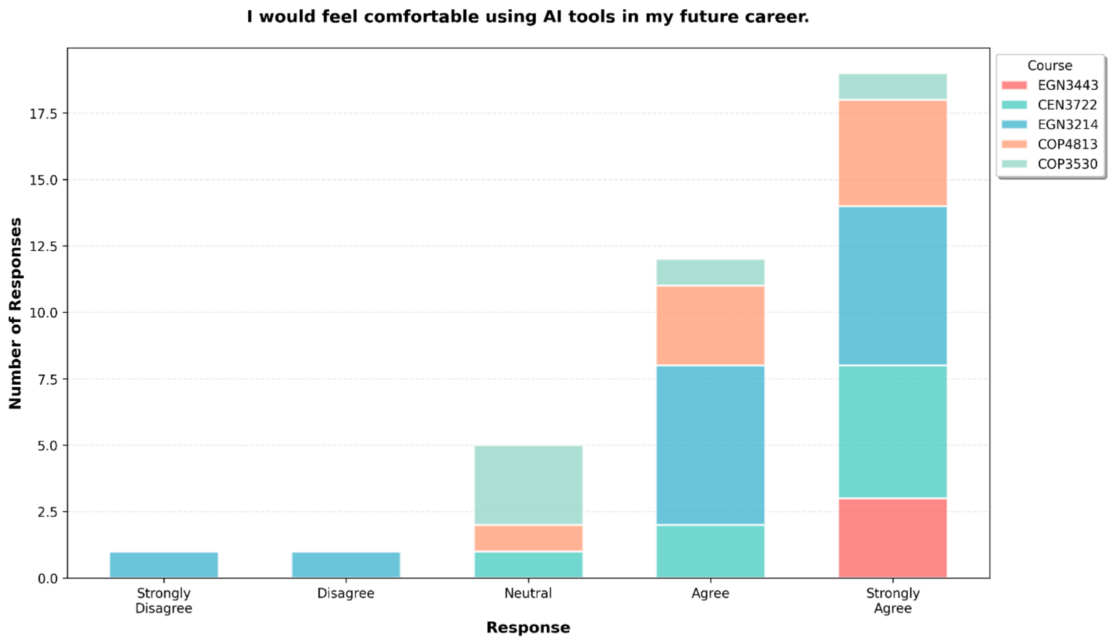

I feel confident using AI tools to solve technical problems
Number of Responses
0
5
10
15
20
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Response
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

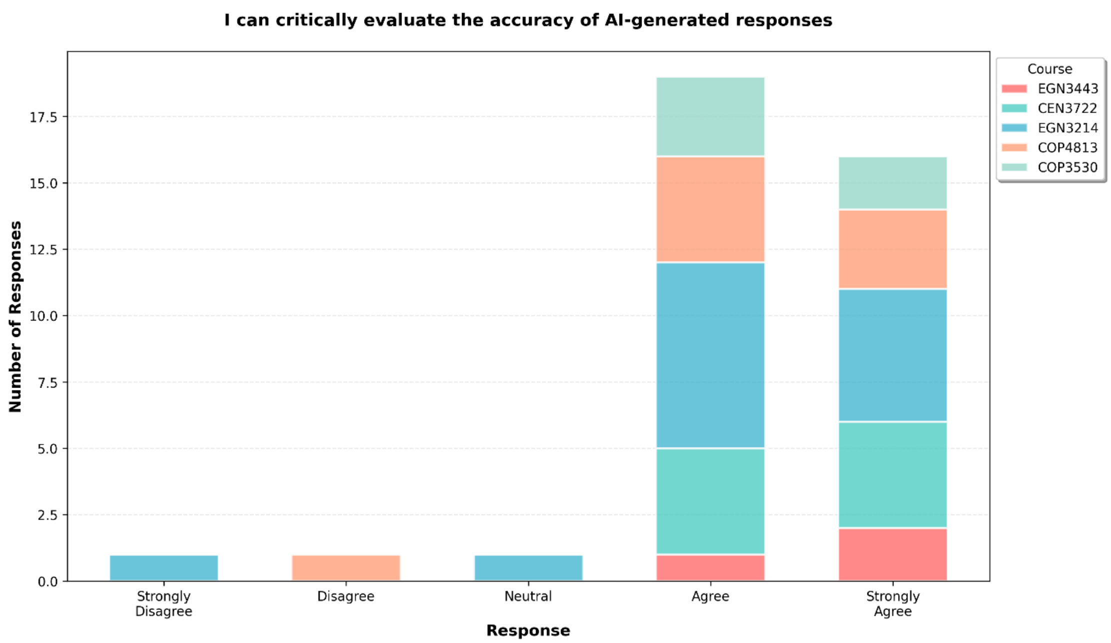


I see AI as a valuable tool for learning new concepts
Number of Responses
0
5
10
15
20
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Response
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

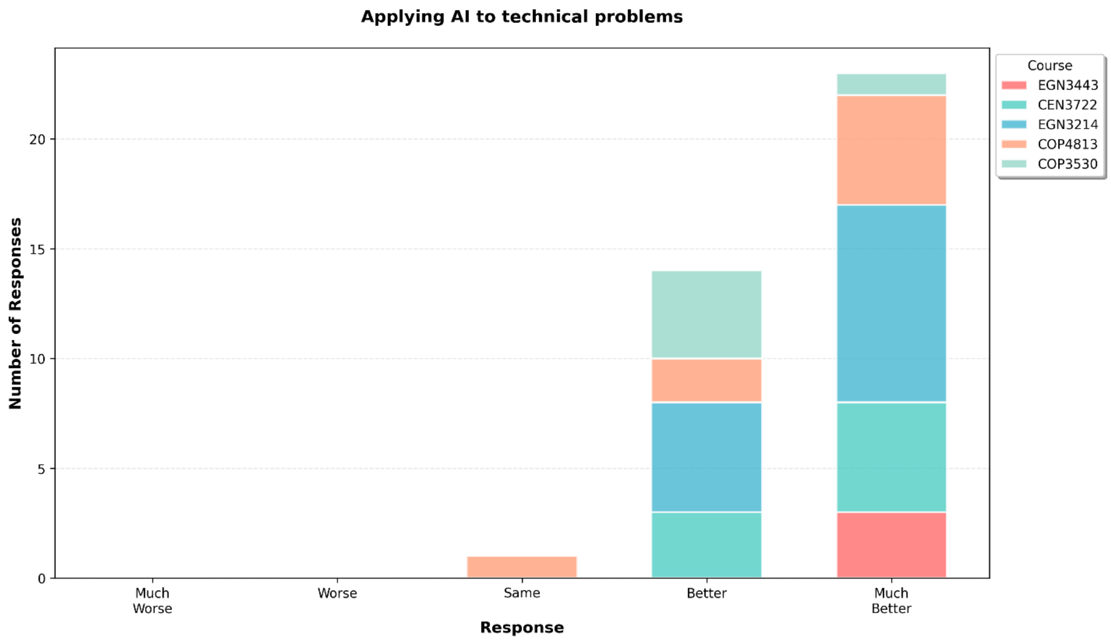


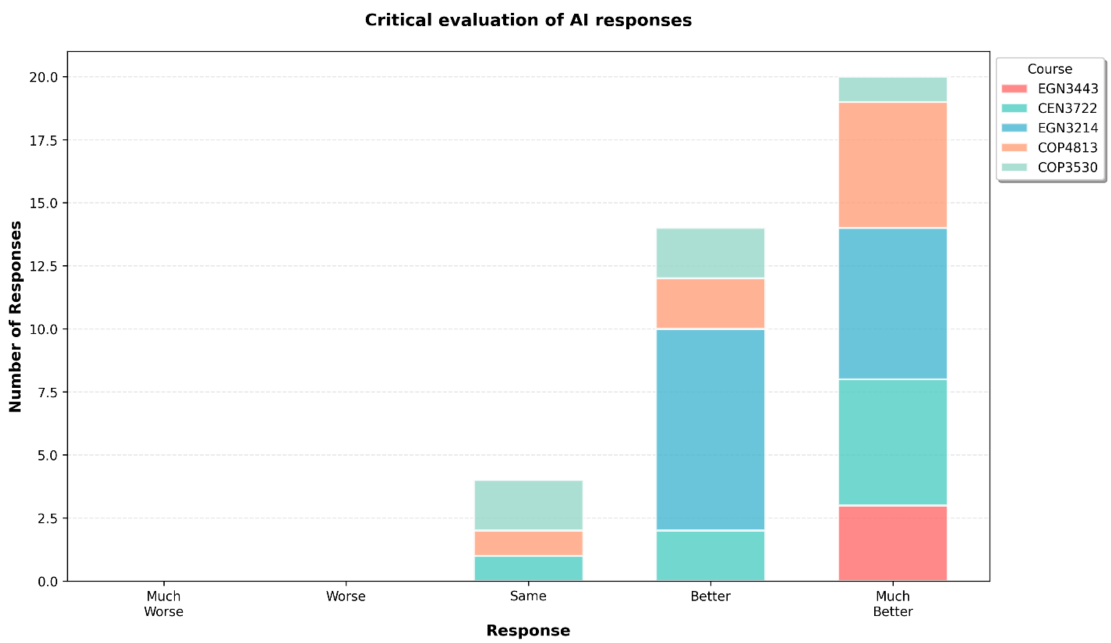
I understand the ethical considerations of using AI in engineering and technical problem solving
Number of Responses
0
5
10
15
20
25
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Response
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

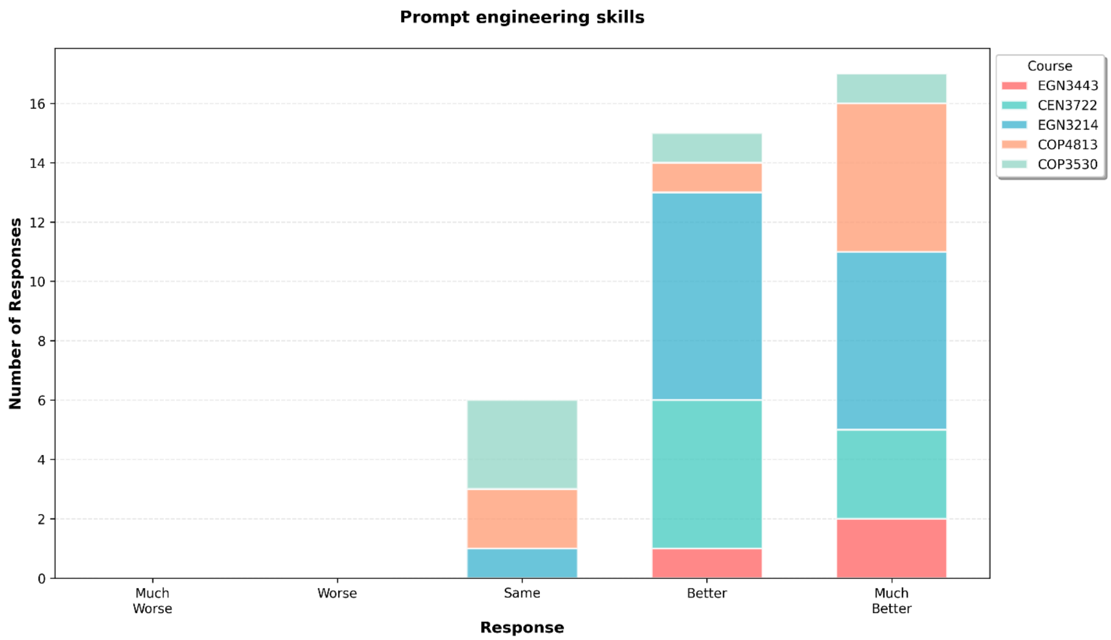

I would feel comfortable using AI tools in my future career.
Number of Responses
Response
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530


I can critically evaluate the accuracy of AI-generated responses
Number of Responses
Response
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

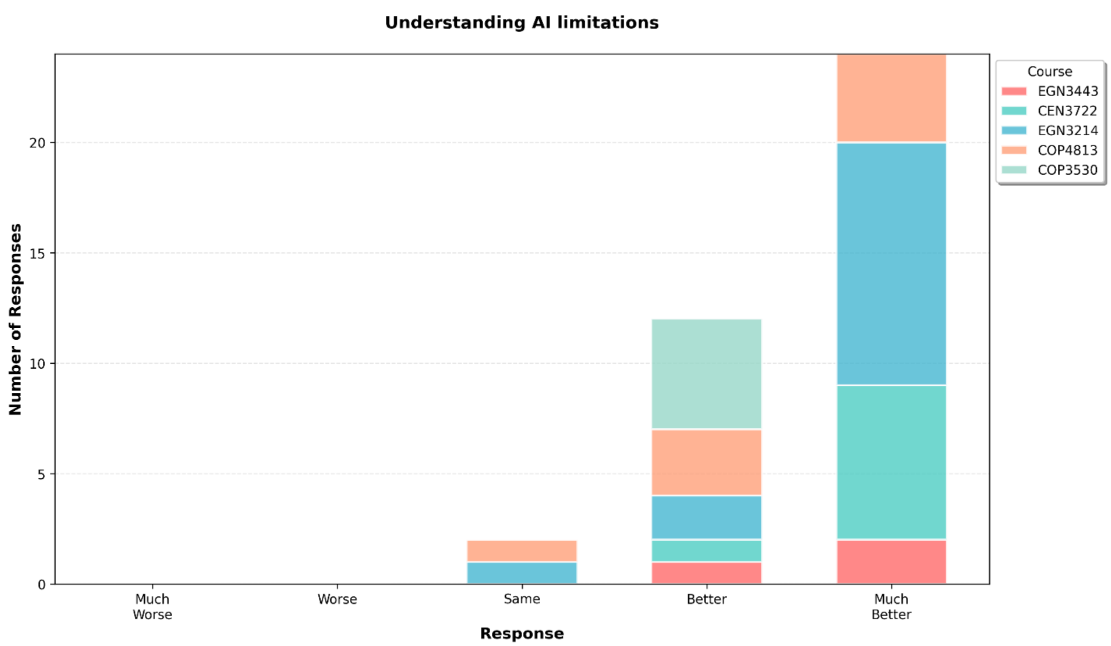
Question 2


Applying AI to technical problems
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530
Number of Responses
0
5
10
15
20
Much Worse
Worse
Same
Better
Much Better
Response


Critical evaluation of AI responses
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530
Number of Responses
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Much Worse
Worse
Same
Better
Much Better
Response

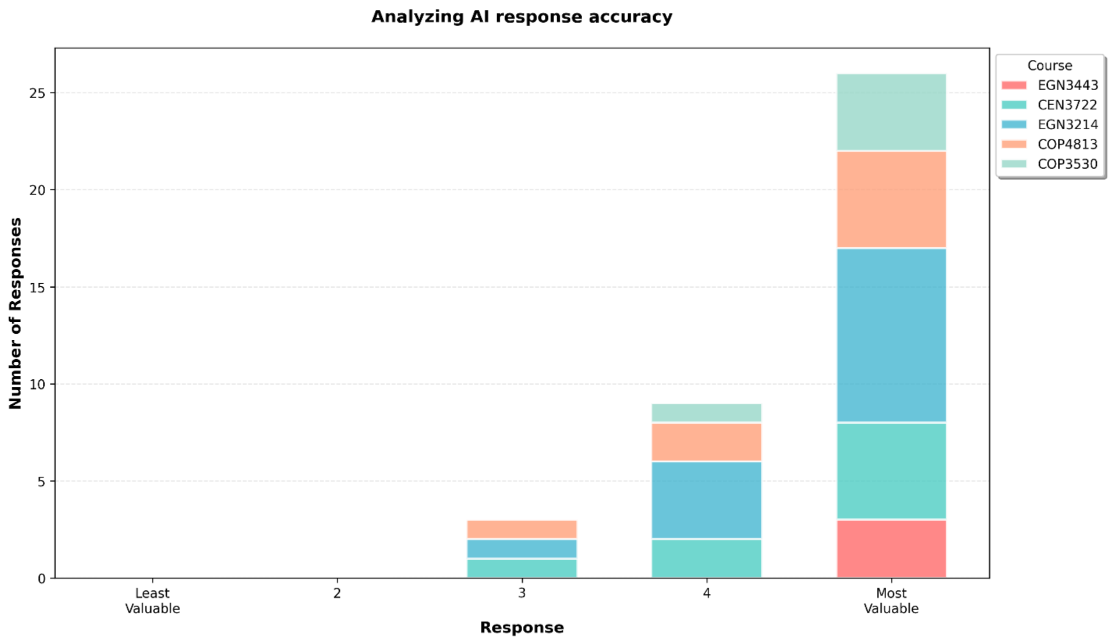


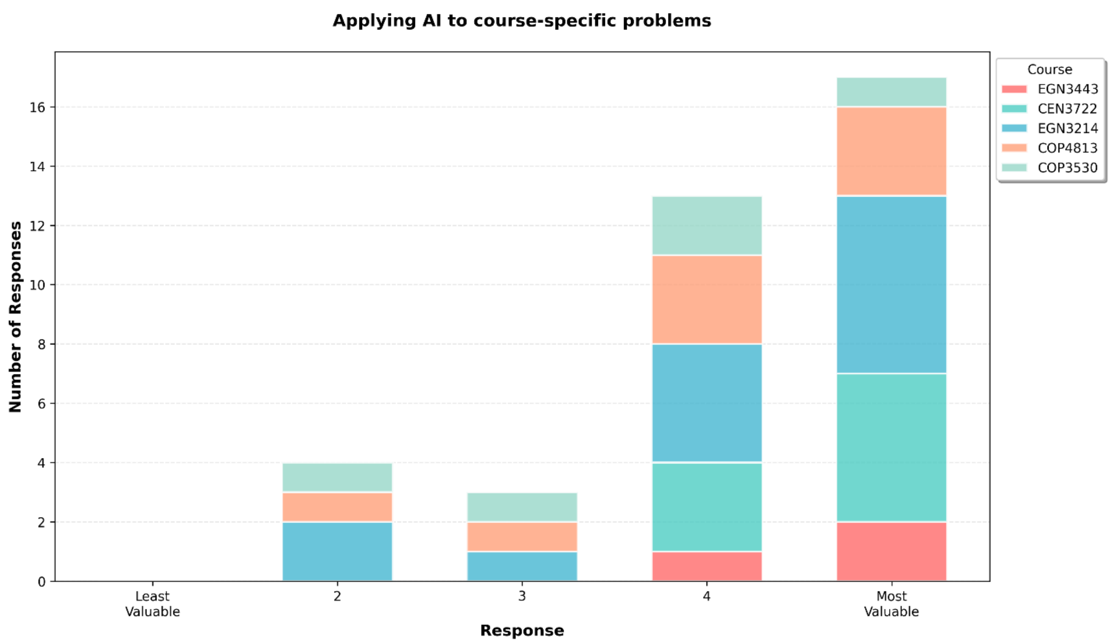
Prompt engineering skills
Number of Responses
0
2
4
6
8
10
12
14
16
Much Worse
Worse
Same
Better
Much Better
Response
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

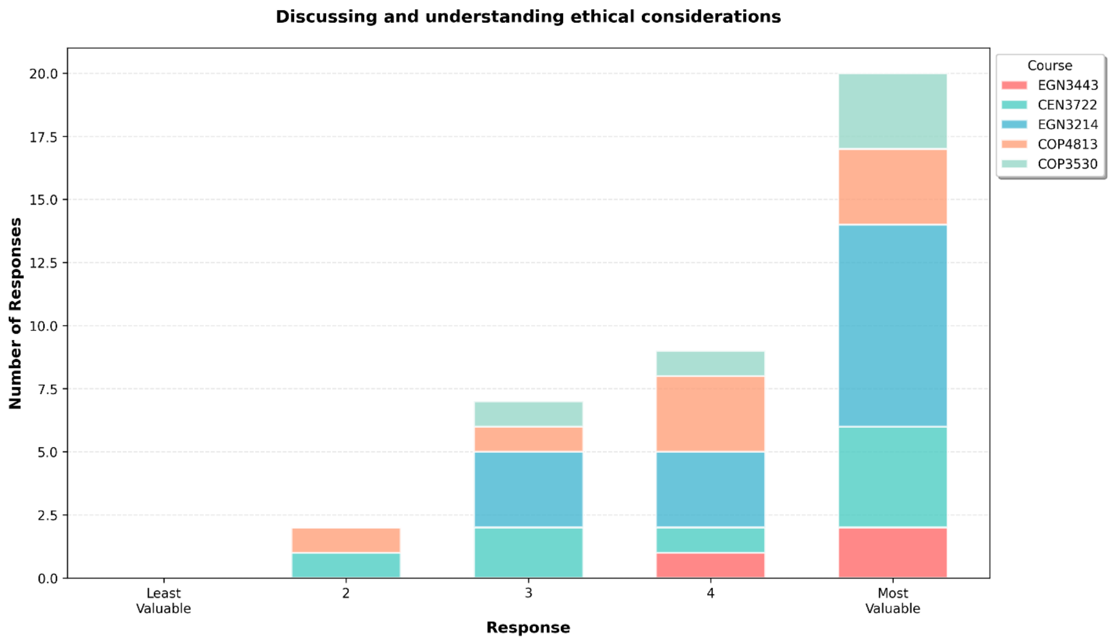


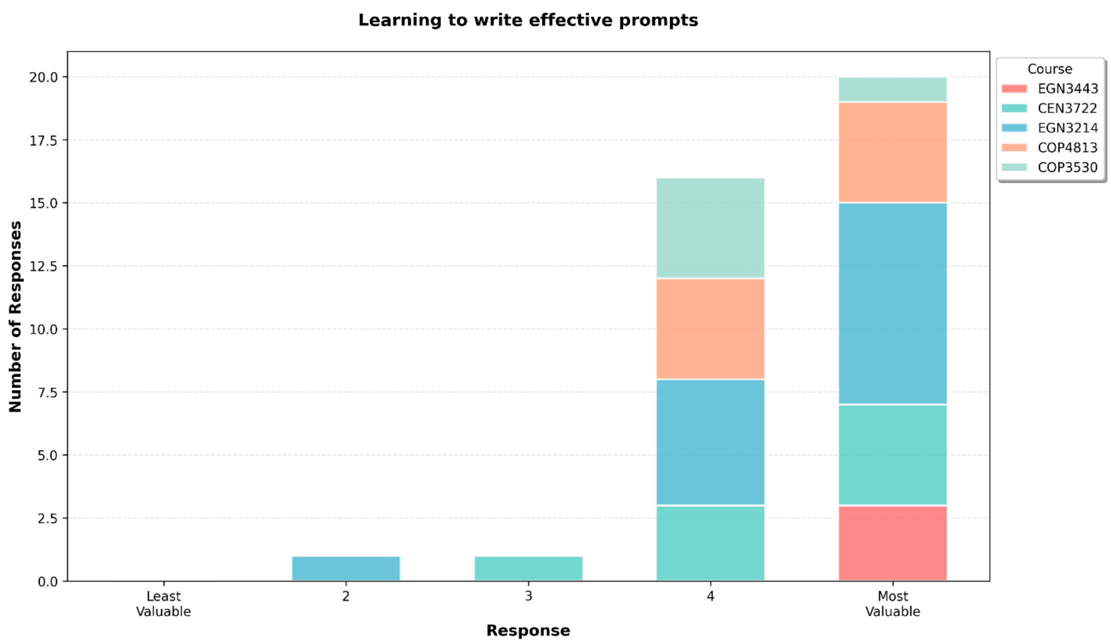
Understanding AI limitations
Number of Responses
0
5
10
15
20
Much Worse
Worse
Same
Better
Much Better
Response
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

Question 3

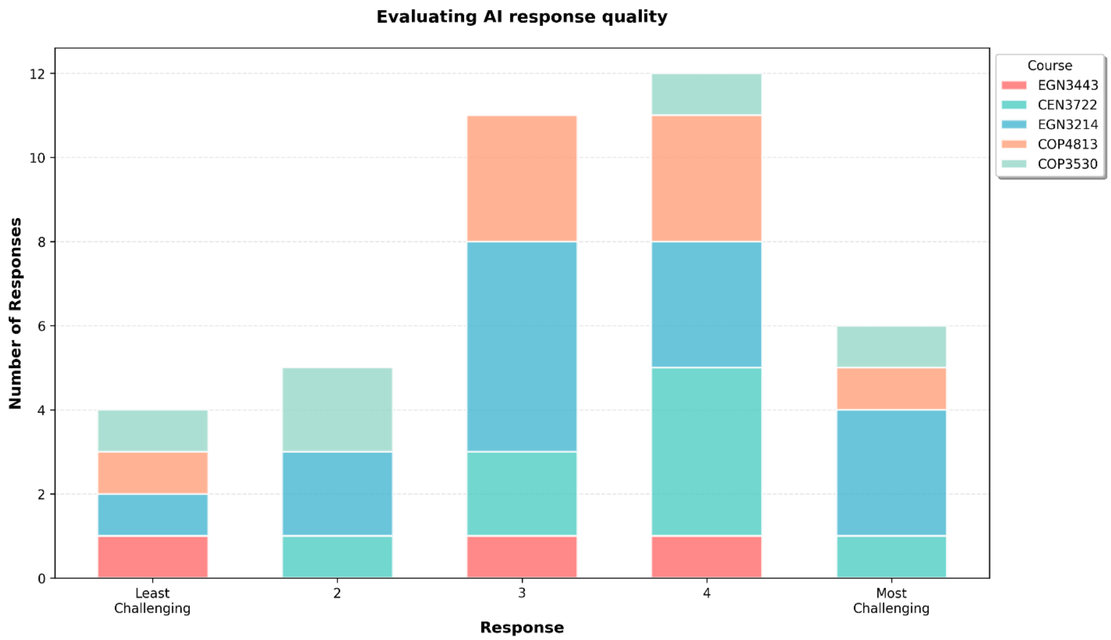

Analyzing AI response accuracy
Number of Responses
Response
Least
Valuable
2
3
4
Most
Valuable
0
5
10
15
20
25
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

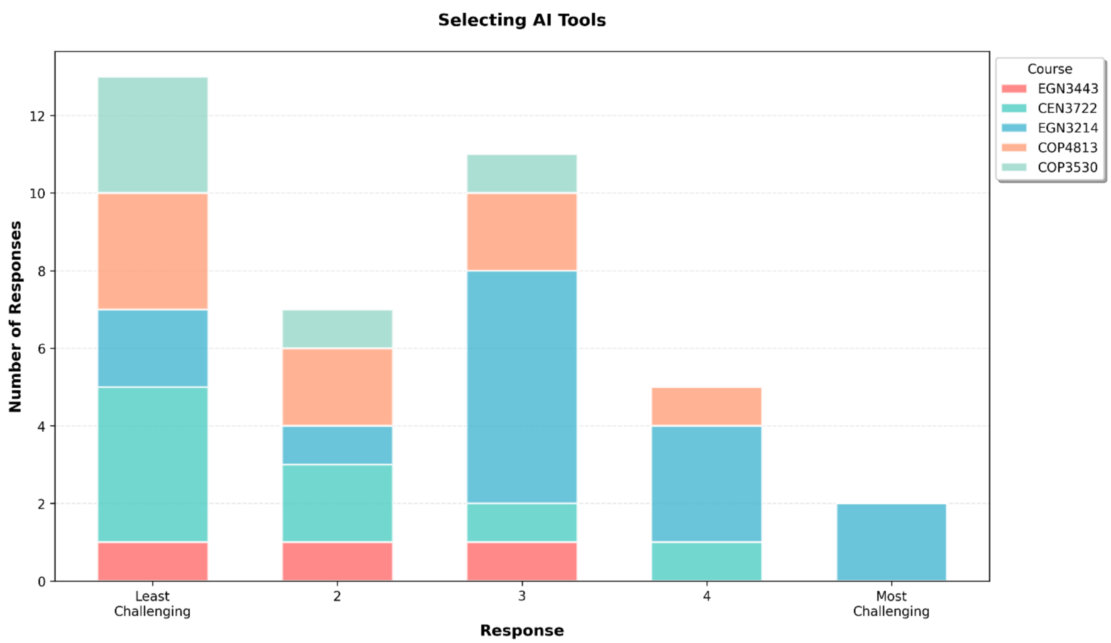

Applying AI to course-specific problems
Number of Responses
Response
Least
Valuable
2
3
4
Most
Valuable
0
2
4
6
8
10
12
14
16
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

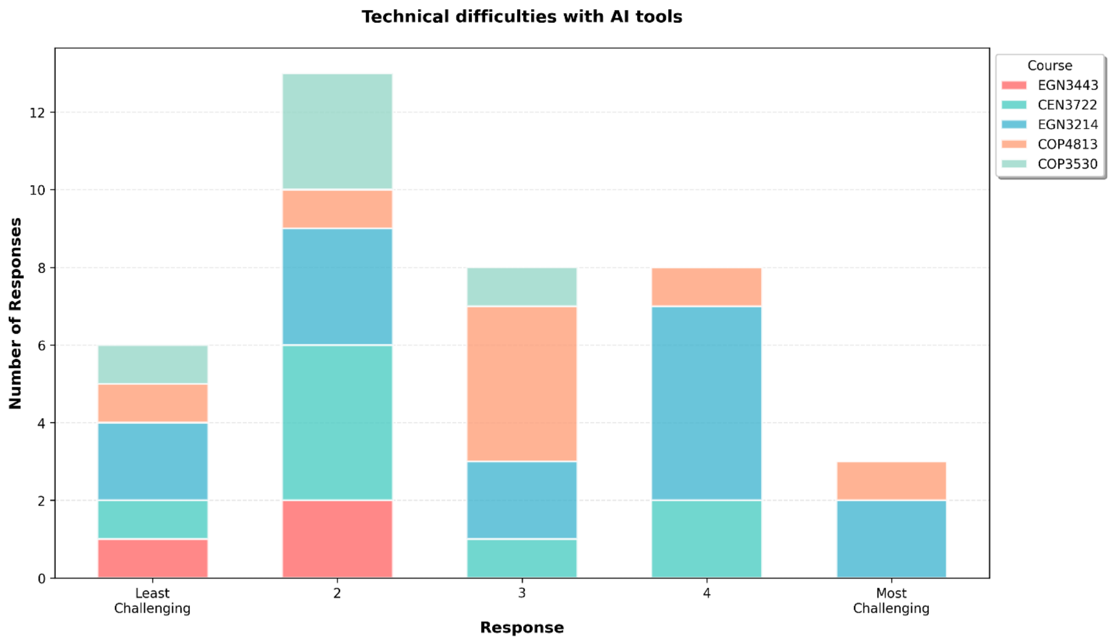

Discussing and understanding ethical considerations
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530
Number of Responses
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Least
Valuable
2
3
4
Most
Valuable
Response

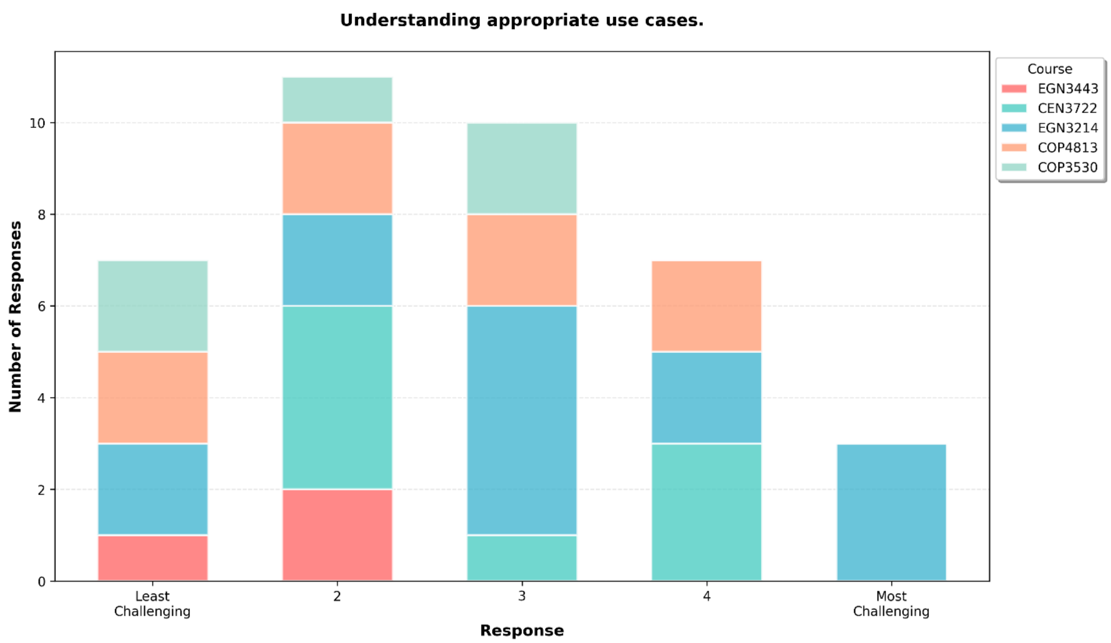

Learning to write effective prompts
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530
Number of Responses
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Least
Valuable
2
3
4
Most
Valuable
Response

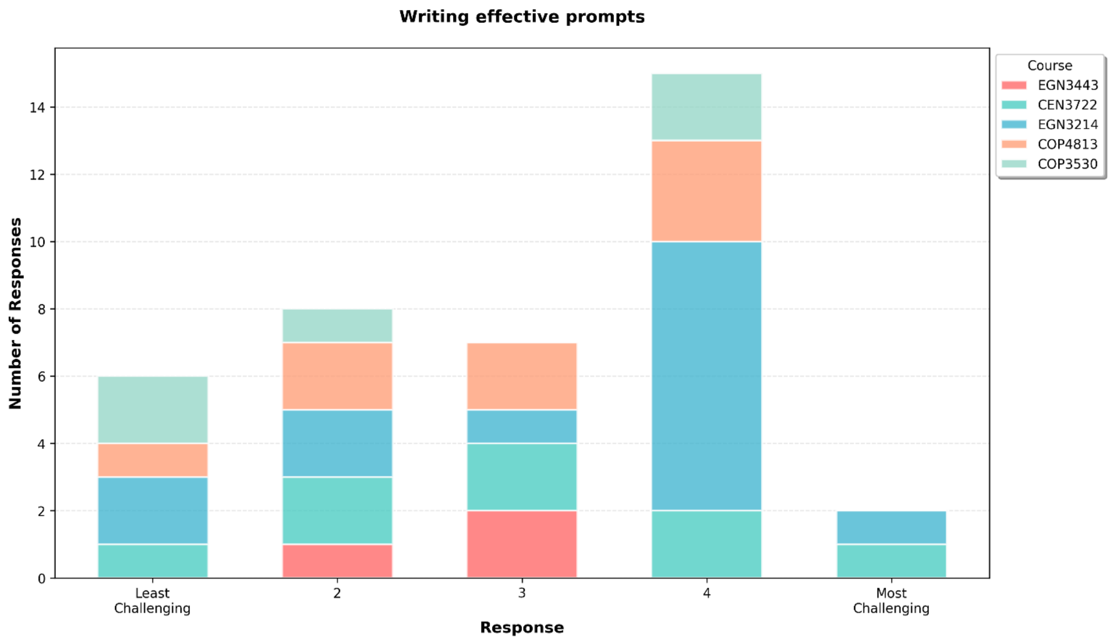
Question 4


Evaluating AI response quality
Number of Responses
Response
Least Challenging
2
3
4
Most Challenging
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530


Selecting AI Tools
Number of Responses
Response
Least Challenging
2
3
4
Most Challenging
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

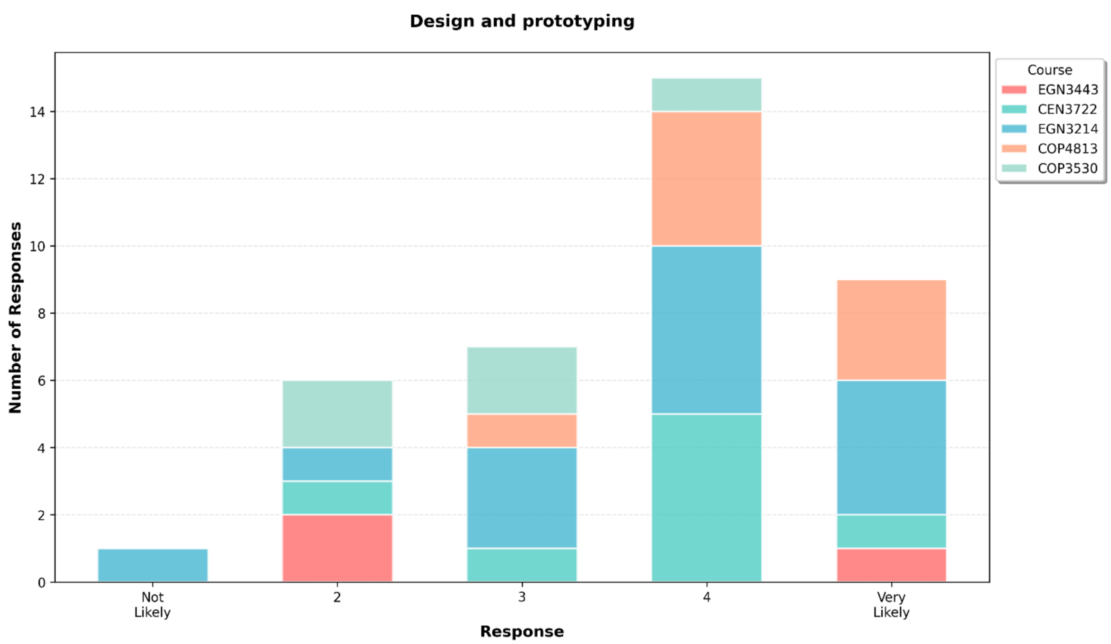

Technical difficulties with AI tools
Number of Responses
Response
Least Challenging
2
3
4
Most Challenging
0
2
4
6
8
10
12
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530


Understanding appropriate use cases.
Number of Responses
Response
Least Challenging
2
3
4
Most Challenging
0
2
4
6
8
10
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530

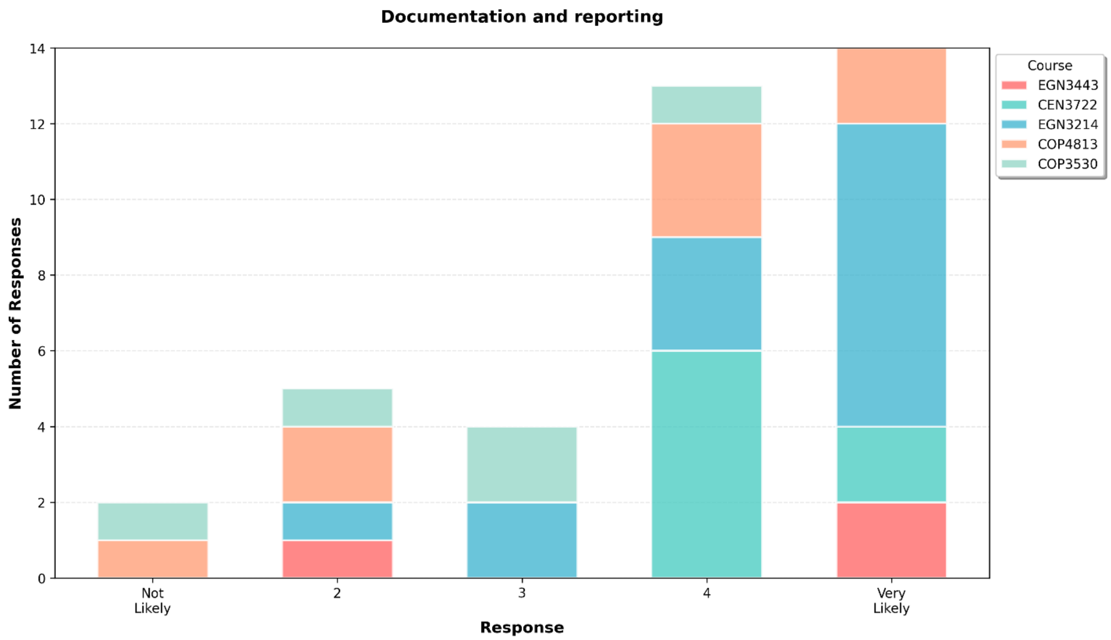


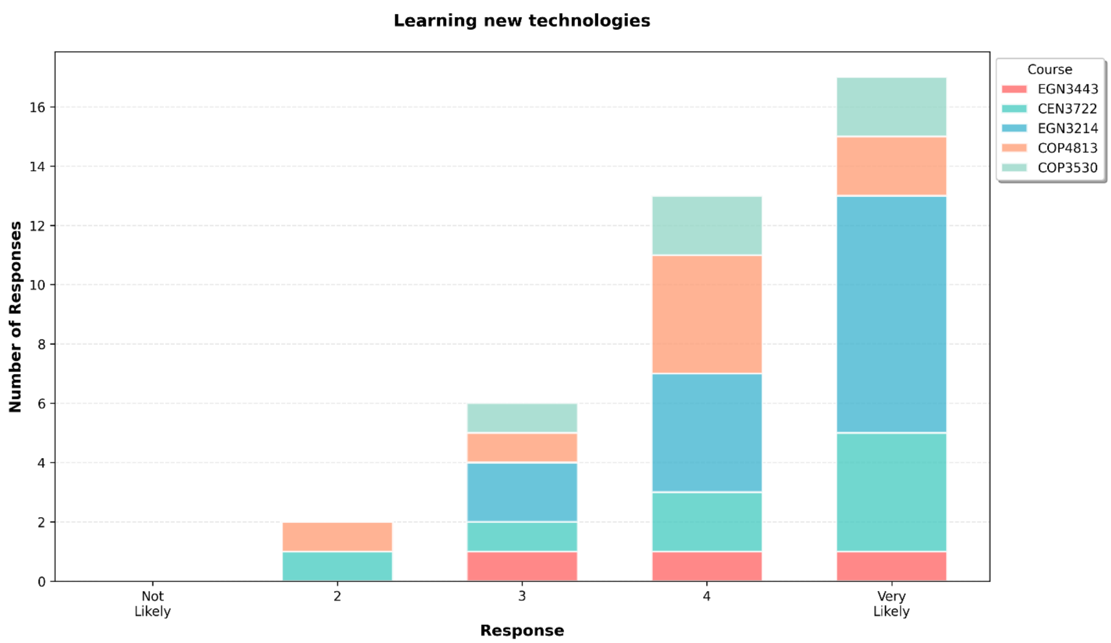
Writing effective prompts
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530
Number of Responses
0
2
4
6
8
10
12
14
Least
Challenging
2
3
4
Most
Challenging
Response

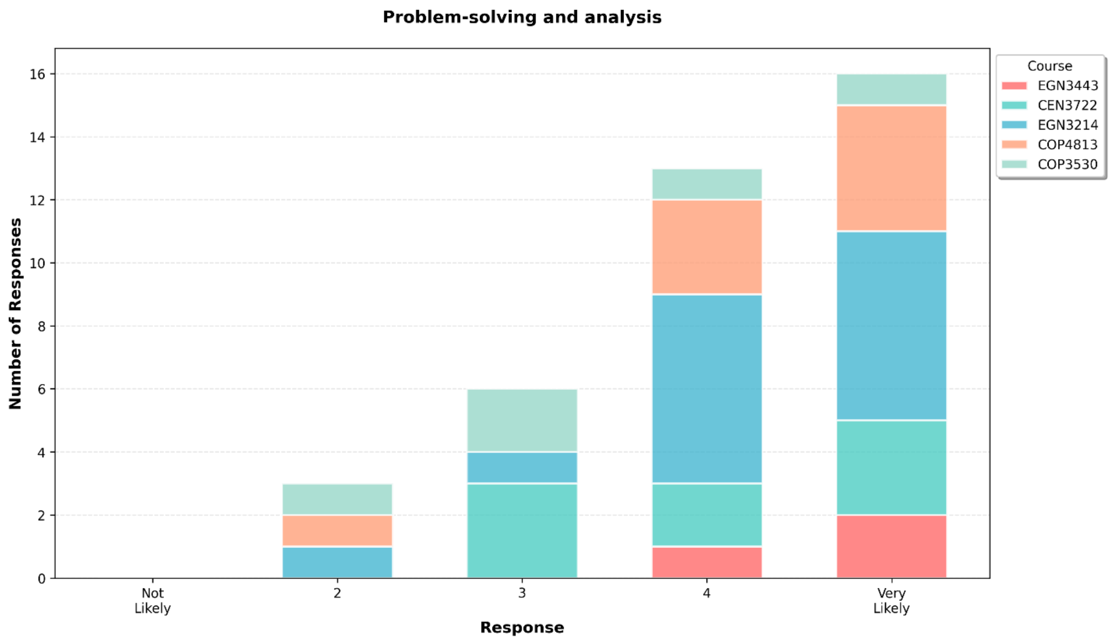
Question 5

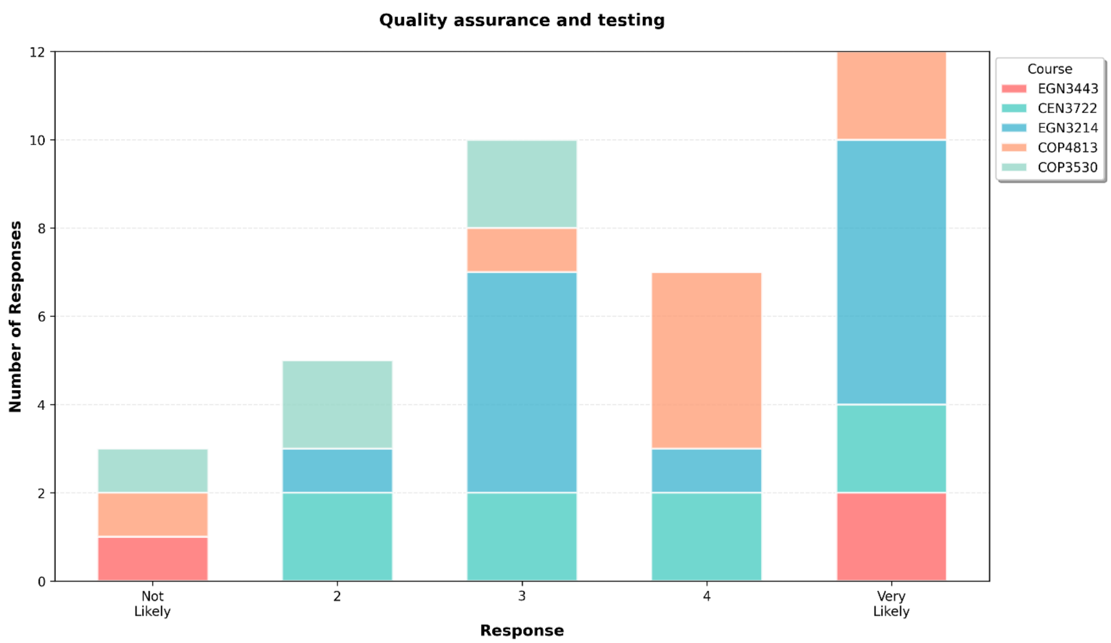


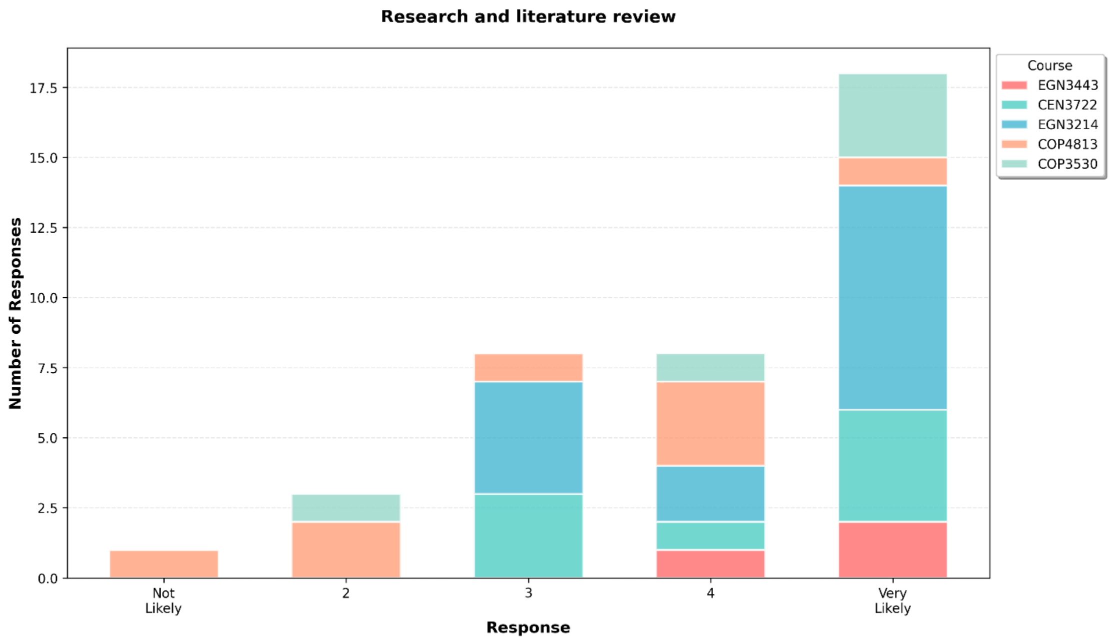
Design and prototyping
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530
Number of Responses
0
2
4
6
8
10
12
14
Not
Likely
2
3
4
Very
Likely
Response


Documentation and reporting
Number of Responses
Response
Not Likely
2
3
4
Very Likely
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530


Learning new technologies
Number of Responses
Response
Not Likely
2
3
4
Very Likely
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530


Problem-solving and analysis
Number of Responses
Response
Not Likely
2
3
4
Very Likely
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530


Quality assurance and testing
Number of Responses
Response
Not Likely
2
3
4
Very Likely
Course
EGN3443
CEN3722
EGN3214
COP4813
COP3530



RESULTS: AI SURVEY — OPEN-ENDED RESPONSES

The following presents thematic summaries and representative responses for each open-ended survey question. Responses were collected from students across all six courses.

Question 6: In What Ways Did AI Help Enhance Your Understanding of the Course Material?

Total Responses: 45

Immediate clarification was the most commonly cited benefit. Students received instant explanations without waiting for office hours. AI also provided alternative perspectives, step-by-step breakdowns, error identification in student work, and direction to supplementary resources. The 24/7 availability was frequently characterized as a 'study buddy' function.

Response 1 (COP4708): "AI helped by giving clear explanations, breaking down complex topics, and providing quick examples that made the course material easier to understand and apply."

Response 2 (COP4813): "AI helped enhance my understanding by bringing up concepts that weren't necessarily in the course study material."

Question 7: What Concerns, If Any, Do You Have About AI Use in Engineering Education or Practice?

Total Responses: 42

Over-reliance was the dominant concern, with many students fearing that dependence on AI could erode fundamental problem-solving skills. Academic integrity, accuracy and reliability (hallucinations), loss of critical thinking, job market impact, and uncertainty about appropriate use boundaries were all recurring themes.

Response 1 (EGN3214): "Engineering is intentionally a 'precise' field. This course proved that you need to still have an understanding in engineering when using AI because not all the time will the response be completely accurate. But it's for sure a great tool!"

Response 2 (COP4813): "I'm concerned that people will apply to jobs while being totally unqualified and will still be able to get the job due to using AI."

Question 8: What Improvements Would You Suggest for Future Implementations?

Total Responses: 38

Students most frequently requested clearer guidelines specifying when and how AI may be used. Structured prompt engineering training, in-class demonstrations, dedicated workshops, and more time for ethical discussion were also recommended. A recurring theme was balance: incorporating AI while preserving core learning objectives.

Response 1 (EGN3214): "One improvement I would suggest would be adding a requirement for students to document exactly how they used AI for the assignment, in order for the student to reflect on whether they are using AI properly."

Response 2 (CEN3722): "I believe there should be more focus on making students write their own prompts at least mostly."

Question 9: Can You Describe a Specific Example Where AI Helped You Understand a Concept Better?

Total Responses: 39

Programming and debugging was the most cited domain. Additional examples included mathematical problem-solving, database design, algorithm explanation, and concept visualization through analogies and real-world applications.

Response 1 (CEN3722): "An example where AI helped me understand was when we were planning our workout app. The AI was able to create a rough outline that we were able to develop further and see where I was making mistakes."

Response 2 (EGN3214): "When I was confused about how to use pandas, I ended up asking ChatGPT and it gave me sample code that aided a lot."

Question 10: What Advice Would You Give to Future Students?

Total Responses: 41

Students consistently emphasized: verify everything; use AI as a guide, not a crutch; learn to prompt effectively; compare AI outputs with course materials; and document the AI interaction process to demonstrate genuine learning.

Response 1 (COP4708): "Always double check can't 100% trust AI results. Don't just blindly copy and paste without checking and understanding the material."

Response 2 (COP3530): "Use it wisely and don't abuse it because it's a powerful tool that can make you very lazy if you aren't using it for the right reasons."

Question 11: Additional Comments

Total Responses: 25

Additional responses were predominantly positive, with students expressing appreciation for having AI formally integrated into coursework. Most indicated that the structured discussions prepared them for modern engineering practice and provided a professional skill they valued. The dominant sentiment was that AI integration, when scaffolded with reflection requirements, is a legitimate and valuable pedagogical tool.

Response 1 (EGN3214): "Thank you for encouraging the use of AI. It has grown me as a professional and I would not have used it if it weren't for this class."

Response 2 (COP4708): "I think people fear what they don't fully understand. AI is wonderful, but don't lose your ability to critically think."

CONCLUSIONS

Effectiveness of the Framework

The systematic pedagogical framework demonstrated significant effectiveness in fostering AI literacy across six technical courses. By utilizing a scaffolded model, the intervention successfully transitioned students from passive consumers of AI-generated content to active, independent problem-solvers. The 'Student Response and Comments' requirement ensured that AI served as a cognitive scaffold rather than a replacement for analytical rigor. The peer comment structure enriched learning by exposing students to variation in AI responses to similar prompts.

Improvements in AI Literacy

End-of-semester surveys indicate high levels of student confidence in utilizing AI for technical problem-solving. A majority reported they could write effective prompts and felt confident using AI tools in future careers. Significant improvements were noted in students' ability to verify AI outputs, with many recognizing the risk of hallucinations in precision engineering contexts. The availability of AI as an on-demand study resource enabled personalized, iterative learning that traditional office hours cannot match in scale.

Future Directions

Future implementations should include formal instruction on advanced prompt engineering and selection of specialized AI tools for specific technical domains. Assignments must continue to evolve to focus on verifying logic and documenting the AI-human collaborative process. Expanded ethical discourse on data security, privacy, and professional boundaries is needed. There is strong justification for expanding this approach to a wider range of engineering and IT coursework and for conducting controlled longitudinal studies to quantify learning outcomes.

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