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Understanding Student Perception and Utility of Generative Artificial Intelligence as a Learning Aid in a Sophomore-level Engineering Course on Electrical Circuit Analysis

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Understanding Student Perception and Utility of Generative Artificial Intelligence as a Learning Aid in a Sophomore-level Engineering Course on Electrical Circuit Analysis

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Background:

This full-length paper reports on an empirical study on the intentional integration of generative artificial intelligence (GAI) tools into a sophomore-level electrical circuit analysis course. The goal was to understand the GAI tools' utility as a learning aid for technical concepts and as an opportunity for students to critically explore implications of using GAI to generate engineering solutions.

GAI tools present the opportunity to transform teaching and learning experiences in engineering. The tools can support students in understanding complex concepts, providing guidance for problem solving, and efficiently completing assignments [1] - [3]. However, the effective integration of GAI in engineering education will require a balanced approach that supports the use of these tools while cultivating practice among students to critically evaluate and validate GAI-generated solutions [4]. On a deeper level, the inquiry into decision-making regarding how and why to use GAI in course-learning tasks requires students to reflect critically on their own sense of purpose and agency in learning. Emerging literature is also beginning to define GAI literacy as a way to understand how learners interpret, evaluate, and engage with GAI systems; such work offers important foundations for researchers seeking to characterize student use and comprehension of these tools [5] - [7].

Goal of the study:

In the present study, we focus on both the use and critical reflection on the use of GAI by students in a foundational electrical engineering course. Our research question was: Do guided opportunities to use and critically reflect on GAI tools in an engineering course build awareness of technical and ethical considerations of GAI use among engineering students?

We adopted this research question with the expectation that the introduction of opportunities to use GAI in our course would, at a minimum, increase students' awareness of important engineering and ethical considerations. This increased awareness is an essential element of engineering students' capacity to think intentionally when making choices about how they use GAI, a basic assertion of pedagogical frameworks that focus on critical thinking [8].

To deepen our understanding of how opportunities to critically reflect on GAI tools might impact student learning in our engineering course, we took assumptions from Julianne Code's "Agency

Theory" for adult learning to develop educational interventions to not only build awareness among students but also increase their self-motivation as learners. According to Code [9], "Learner agency is an emergent capacity that is intentional, self-generated, and responsive to social factors in the learning context." Our study sought to explore whether timely opportunities for students to engage in their own critical examination of the intersection of GAI tools and their learning objectives might support critical thinking skills as well as an increased sense of learner agency in the course (see Fig. 1). In this study, the incorporation of GAI tools is understood as a disruptive element within the traditional learning environment—one that creates a productive space for critical interest and reflection. Framed through Code's Agency Theory, this disruption becomes an opportunity for learners to engage more intentionally with their learning processes, thereby strengthening critical inquiry and supporting the emergence of learner agency.

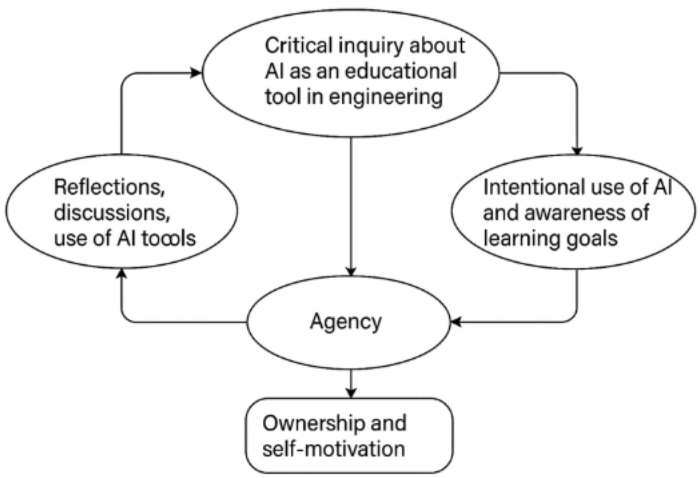

Fig. 1. Process model for leveraging critical inquiry about use of GAI to increase agency in learners, resulting in enhanced self-motivation.

Methods:

As an exploratory investigation, the goal of this study was to generate insights into the ways GAI tools may be used productively in engineering education and to identify questions that merit deeper examination in future research [10]. Through the process of thematic coding, researchers also identified connections to qualitative analytic frames and observed alignment with elements of Code's Agency Theory. While these frames could inform the development of more structured future research instruments, such steps were beyond the scope of the present study.

Data collection:

Data for this study were collected in tandem with regular course implementation, consistent with qualitative research frameworks that emphasize contextualized inquiry conducted within authentic learning environments [11] - [12]. Engineering students at Oregon State University are required to complete a series of three sophomore-level courses on electrical engineering fundamentals. The courses are each ten weeks long and typically taken sequentially. This study was conducted in a section of the first course (ENGR 201) of the series. Most of the 132 students enrolled in the section intended to pursue mechanical engineering for their baccalaureate degree. The Institutional Review Board (IRB) determined this study as exempt from review for protection of human subjects.

ENGR 201 introduces Kirchhoff's voltage and current laws, and analysis techniques for resistive circuits and first order RC and RL circuits. Graded components of the course included homework, laboratory and recitation assignments, and exams. The homework and laboratory/recitation components constituted 25% each of the overall grade. Two midterm exams at 15% each and a comprehensive final exam at 20% made up the remaining 50% of the total grade. Students were allowed to use GAI tools of their choice for the homework and laboratory/recitation assignments. Use of GAI tools was not permitted for the exams. Thus, components that allowed use of GAI tools were weighted equally in determining student grades with components that disallowed their use. The reasoning for disallowing GAI use for exams was as follows: GAI use in the course was intended as a tutor or learning aid to strengthen skills, while the purpose of the exams was for students to demonstrate their ability to apply those skills independently and thereby, demonstrate their unaided understanding of underlying engineering concepts.

The syllabus included an explicit section on class policy for GAI use. An instructor-led demonstration in the first week of class modeled the use of prompts with a licensed version of Microsoft Copilot (the university-supported GAI tool) while also cautioning students that GAI-generated solutions could be incorrect and an understanding of circuit analysis techniques was essential to evaluating and validating the solutions (see example in the Appendix). As such, some of the homework assignments included GAI-generated solutions to problems wherein the students were asked to identify and correct errors, if any (see Appendix). Each homework assignment required students to acknowledge their use of GAI tools by answering a simple yes or no question, thereby modeling ethical usage of the tools. There was no penalty for responding in the affirmative. Response to this question was mandatory for the homework to be considered for grade credit. For the scope of this study, the binary response to usage of GAI produced a baseline context of use trends for the class, and no more nuanced information was collected. Future studies might further investigate the spectrum of use behaviors.

Additionally, during week 3 and week 9 of the term, students were asked to reflect on the usefulness of GAI tools in supporting their learning and their perception of how GAI tools are or should be used in engineering professions. These reflections were collected as mandatory responses to prompts on online discussion boards. Of the 132 students enrolled in the course, 121 or about 92% participated in the discussion assignments. The discussion questions provided rich, contextualized responses that allowed for deeper exploration of how course participants related to GAI as learners, both at specific points in time as well as a transitional process, evolving throughout the term.

Weeks 3 and 9 were selected for student reflections in part due to their convenient alignment with the course schedule. These points in the term provided natural moments for students to reflect on their learning progress and their evolving use of GAI tools. The prompts used in these weeks were intentionally designed to be both simple and open-ended so that students could respond comfortably while also ensuring that instructors and researchers could interpret the responses consistently. The prompts directly aligned with the exploratory nature of the research question, making them appropriate for an investigation seeking to understand emerging patterns rather than to test predetermined hypotheses. The first discussion assignment in week 3 used the prompts: (i) What are the advantages for you of using GAI tools in this course? and (ii) What are the disadvantages for you of using GAI tools in this course? The second discussion assignment in week 9 included an additional prompt: (iii) As a future engineer, what do you consider the most important way in which GAI will serve as a tool for professional engineers? The resulting post content (one post per student for each of the two weeks) addressing all prompts were considered as means to understand students' perspective on and awareness of GAI tools.

Data analysis:

Qualitative coding proceeded by identifying themes that reflected patterns and trends in the overall dataset. Responses were examined for repeated concepts, concerns, and framings that mapped onto the synthesized categories shown in Table 1. These coding decisions were

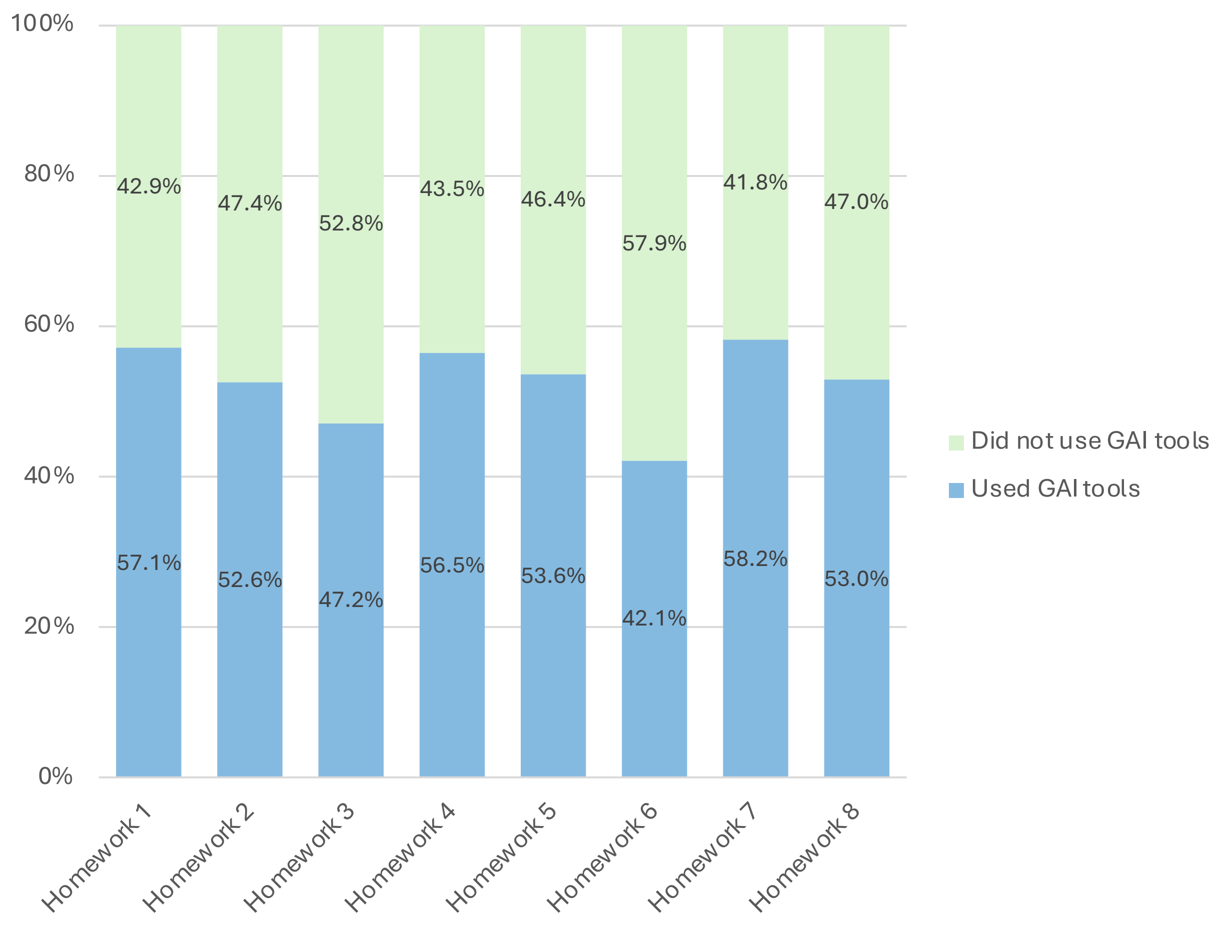

Fig. 2. Use of GAI tools for homework assignments between weeks 1 and 10 of the course. (No homework was assigned in week 5 and week 8—i.e., weeks when the midterm exams were scheduled. Consequently, the homework numbers do not correspond to the week numbers.) The data suggest little change in the use of GAI except for weeks 3 and 7, where GAI use dropped.

necessarily shaped by the researchers' interpretive perspectives and the course context. Because of this, the dataset and findings are not intended to be generalizable; however, generalizability was not the aim of the study.

The responses were coded inductively based on emergent themes and language use. We had hoped that these themes might correspond to Code's model for agency in learning but found that more targeted discussion questions will need to be asked in future studies to understand how students' experiences relate to the agency in learning constructs. For this round of analysis, instead, we focused on common attitudes presented in the responses by the participants. In particular, the variety of attitudes in the responses relating to GAI tools in the learning process were grouped for both week 3 and week 9 (e.g. "a way to get started or to get unstuck" or "an unreliable resource"). In addition, responses were tagged for either use of GAI as the active subject of the statements (e.g. "GAI causes learners to lose out.") or active agent (e.g. "Learners use GAI to check for errors."). This cross section of coded results then allowed for an analysis of advancement in engineering students' critical and ethical awareness of the use of GAI tools, thereby addressing the primary research question.

Results:

Students' reported use of GAI for homework assignments stayed relatively stable between 53% and 58% across the eight homework assignments (see Fig. 2 above). These data suggest little change in the use of GAI, except for weeks 3 and 7 (homework 3 and homework 6), where GAI

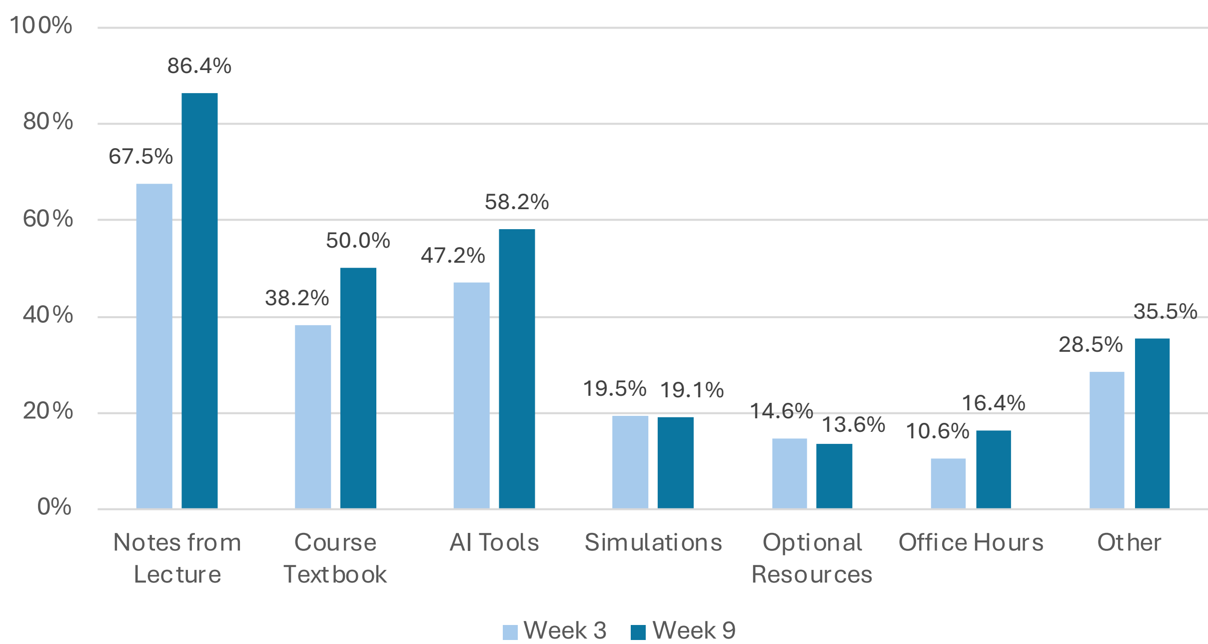

Fig. 3. Student reported use of learning resources for completing homework assignments. Lecture notes dominate, but GAI tools were used in similarly high frequency as the course textbook. Overall, students reported a slight increase in using resources between weeks 3 and 9. (The bin titled 'Simulations' refers to the use of LTSpice software. 'Optional Resources' include notes and videos from the online version of the course made available to the students.)

use dropped. The relatively small decrease in GAI use in these weeks may reflect students' responses in view of the midterm exams that immediately followed these assignments; some may have chosen to spend additional time working through assignments without GAI support to reinforce their understanding. This change in an otherwise stable use of GAI tools may nonetheless merit further exploration in future studies. In weeks 3 and 9, students were requested to also indicate their most used learning resources. As shown in Fig. 3, the students depended heavily on lecture notes with GAI tools serving as a secondary option. The dependence on lecture notes is not surprising given that they were not made available online (other resources such as notes and videos from the online version of the course were made available instead).

The two sets of 121 student responses to the discussion board prompts in week 3 and week 9 revealed a variety of topics that indicated respondents' awareness of and relationship to GAI as tools for learning in engineering. A multiple tagging scheme was used, meaning some responses may have been tagged into multiple coding categories based on their content, and the overall number of tags is not the same as the number of responses. To further synthesize the coded responses, they were bucketed into the categories listed in Table 1.

Table 1: Coding categories used in analyzing student responses on their use of GAI tools

Note Label	**Merged / Synthesized Category**
Getting started	Support for problem initiation
Getting unstuck	Support for problem initiation
Convenience	Convenience / accessibility
Accessibility	Convenience / accessibility
Conceptual help	Conceptual clarification
Clarification	Conceptual clarification
Unreliable resource	GAI correctness concerns
Hallucinations	GAI correctness concerns
Overreliance	Reduced learner effort / overreliance
Reduced effort	Reduced learner effort / overreliance
GAI-centered framing	GAI-centered framing
Learner-centered framing	Learner-centered framing
Ethical concerns	Ethical / responsible use awareness

Responsible use	Ethical / responsible use awareness
Does not use GAI	Does not use GAI
Busy work	Reference to busy work

The responses have been bucketed from the tags or labels in the left column to the synthesized categories in the right column. Below are explanations of the synthesis process for each category as well as examples from student responses that illustrate each.

1. *Support for Problem Initiation* was grouped from: *Getting started* and *Getting unstuck* and is used when students described GAI helping them begin or approach unfamiliar tasks.
    - "GAI helps me get started when I don't know where to begin."
    - "It shows me the first step when I'm stuck."

2. *Conceptual Clarification* was grouped from: *Conceptual help* and *Clarification* and is used when students described GAI deepening their understanding or explaining concepts.
    - "It explains things in a way I can understand better than the textbook."
    - "GAI helps me grasp the theory behind the problem."

3. *Convenience / Accessibility* was grouped from: *Convenience* and *Accessibility* and is used when students emphasized speed, availability, or ease of use.
    - "It's fast and available anytime, even when office hours aren't."
    - "I use it because it's easier than waiting for help."

4. *Reduced Learner Effort / Overreliance* was grouped from: *Overreliance* and *Reduced effort* and is used when students expressed concern about laziness or avoiding cognitive effort.
    - "It makes me lazy — I just ask instead of thinking."
    - "I rely on it too much and don't learn the material."

5. *GAI Correctness Concerns* was grouped from: *Unreliable resource* and *Hallucinations* and is used when students noted GAI giving wrong answers or misleading explanations.
    - "GAI is often wrong and gives confusing steps."
    - "It hallucinated a formula that doesn't exist."

6. *Does Not Use GAI* is a standalone category used when students explicitly stated they do not use GAI tools.
    - "N/A because I don't use GAI for this course."
    - "I prefer to solve problems without GAI."

7. *Ethical / Responsible Use Awareness* was grouped from: *Ethical concerns* and *Responsible use* and is used when students reflect on appropriate boundaries or ethical risks. These responses typically reflected concerns about uses of GAI that students viewed as unnecessary due to potential harm to work ethic, compromised learning, or

environmental overconsumption, as well as uses that would constitute cheating or violate assignment-creation policies.

- "We shouldn't rely on GAI too much — it's not always ethical."
- "I think it should be used responsibly, not to cheat."

8. *Reference to Busy Work* is used when students described *GAI helping with repetitive or low-value tasks*.
   - "It's great for handling tedious calculations."
   - "I use it for the busy work so I can focus on harder stuff."

Week 3 responses, as shown in Fig. 4, demonstrated a high focus on utilization of GAI tools to begin tasks when students felt they did not know where to begin or lacked understanding of initial steps. This was reflected in the category *Support for problem initiation*, mentioned by approximately 34% of student responses. About 70% of the responses expressed concern about *Reduced learner effort / overreliance*, highlighting student awareness of the risks of depending too heavily on GAI tools. There were also a large number of students who mentioned concerns with the correctness of GAI tools (52%) and who saw concept clarification as an advantage (57%). Overall, week 3 responses showed early patterns of how students positioned GAI in their learning, with many still exploring its role in initiating tasks and navigating their understanding of course concepts. However, they also demonstrated eagerness to discuss their concerns about GAI and their strategies for using it. This eagerness to discuss the topic seems to have resulted in an overall robustness of the responses in week 3.

In the week 9 responses (also shown in Fig. 4), the portion of responses representing those who relate to GAI as a tool for initiating tasks *("Support for problem initiation")* decreased to approximately 28% of all responses and about 52% of the responses mentioned using it for increased understanding, or *"Conceptual clarification."* In week 9 more respondents reported the advantage of convenience (29%). Also, many more than in week 3 referenced using GAI for busy work (30%). In week 9 compared to week 3, less respondents (45%) mentioned correctness concerns, and the percentage mentioning reduced learner effort decreased to 52%. Less than a percent of responses addressed ethical use in week 9, down from about 6% in week 3.

Overall, perhaps the most significant result is that the week 9 responses were more focused on the use of GAI to help with busy work as well as convenience and accessibility of information as advantages and, while there was still concern expressed with correctness issues and the tendency for learner overreliance, these concerns were reduced overall, along with any larger ethical concerns for GAI. This shift might be interpreted as an increased level of comfort with GAI tools based on direct experience with them. While awareness in week 3 may have largely been based on second-hand information and fears about the dangers of AI, awareness later (in week 9) was based on first-hand experience with the tools. Also, though it may be desirable from a critical and ethical perspective for future instructors to support increased ethical awareness by including more content related to that topic, it is still notable that the awareness based on first-hand experience for students is likely more grounded in students' own reality. Through the process of building a stronger basis of experience for students on which to form their own opinions about GAI tools, their awareness of the tools, agency as learners and ability to make decisions about how they will use such tools in the future all increased.

Another important result is the potential for additional data to be collected using similar methods that provide more robust responses and allow for deeper analysis of the evolving process of awareness as students encounter and critically consider GAI tools. The authors will continue to explore additional educational action research focused on deepening engineering students' awareness of not only the potential uses of GAI tools but also their relationship to and critical awareness of GAI tool use, possibly resulting in an increase in learner agency.

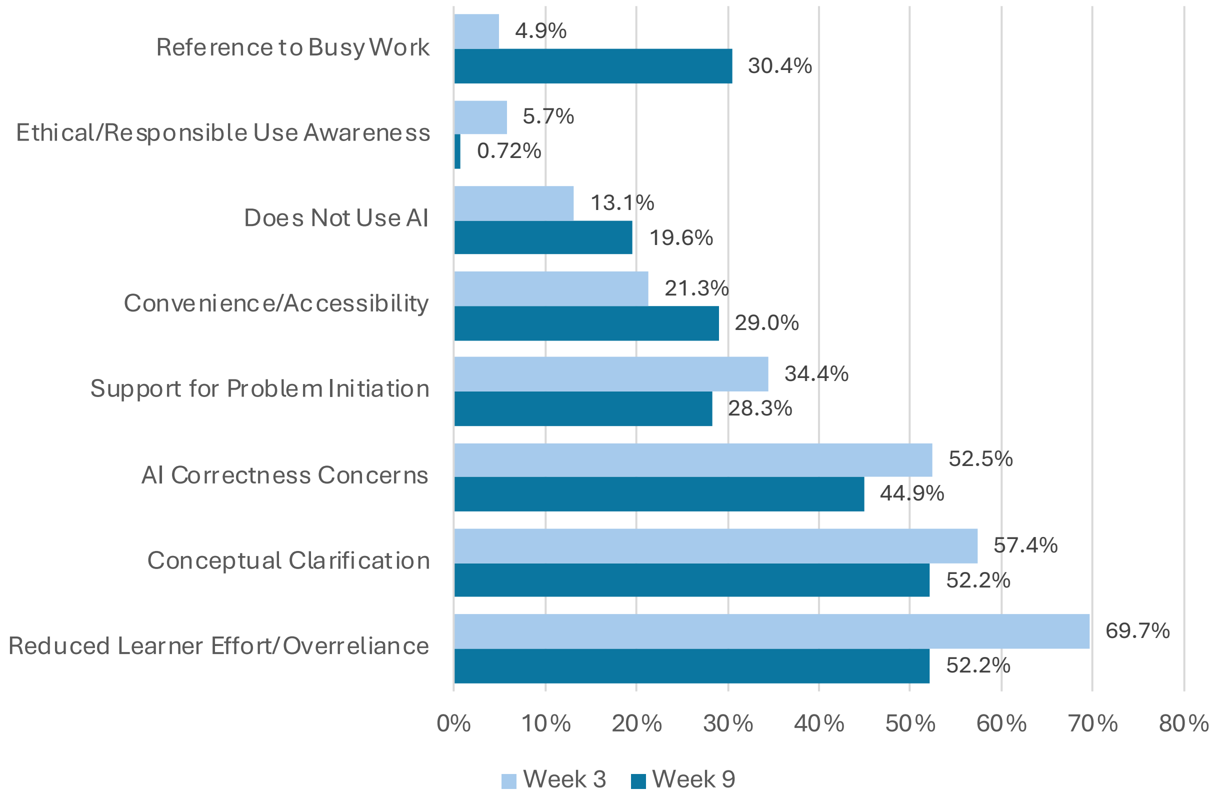

Fig. 4. Total percentages of coded responses that mention each topic addressing student use of GAI in week 3 and week 9 as side-by-side bars. Responses mentioned multiple topics.

Conclusion:

Integration of GAI tools in electrical engineering courses is still in its early days. Training students in the judicious use of GAI to support their learning and critical thinking skills will be key to harnessing the benefits of the technology in engineering instruction. Student perspective of and engagement with GAI will likely also evolve as the tools improve, and their use in engineering courses becomes more established.

From this limited-scope study, some of the results provide clear indication that the discussion prompts gave engineering students meaningful opportunities to critically consider GAI tool use and their relationship to GAI as learners. While some of them chose not to use GAI, they were still exposed to it through the course and undertook this consideration. While some respondents' negative and cautious impressions of GAI tools did not change over the 6 weeks between discussion prompts, exposure to opportunities to use and critically discuss the tools did change the overall outlook of the responses from concern with the harms of GAI to a more practical focus on how they might be used wisely to support learning. Based on the observation that participants' awareness of their relationship as learners to GAI tools shifted from second-hand perspectives to first-hand experience-based opinions, the research hypothesis question can be confirmed. I.e., yes—guided opportunities to use and critically reflect on GAI tools in an engineering course build awareness of technical and ethical considerations of GAI use among engineering students. As a result, we conclude the usefulness of intentional introduction of GAI tools into engineering courses, particularly since it does not burden the instructor with significant additional effort.

Further, the other unexpected result mentioned above is the change among many participants from a focus on concerns for harm to a recognition of the advantages of practical and conscientious uses, a shift which offers insight for future instructors into the basis for perspectives about GAI that students may bring with them. This insight also suggested that future researchers might more deeply explore not just whether awareness is increased, but also the process leading to it, and how it might contribute to enhanced sense of agency and ownership among learners. The research team plans to undertake this exploration in future stages of the study. More broadly, there is potential for the data collection methods used here to be duplicated in other programs where researchers hope to gain understanding of the process of building critical awareness and agency among learners through similar investigations of the relationships between engineers, learners, tasks, and tools.

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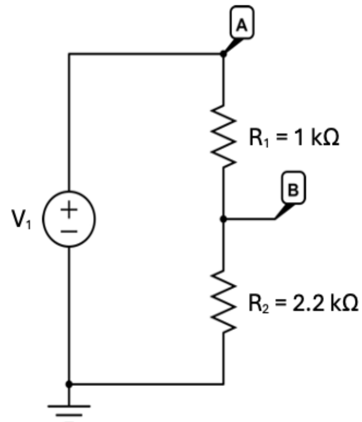
Appendix:

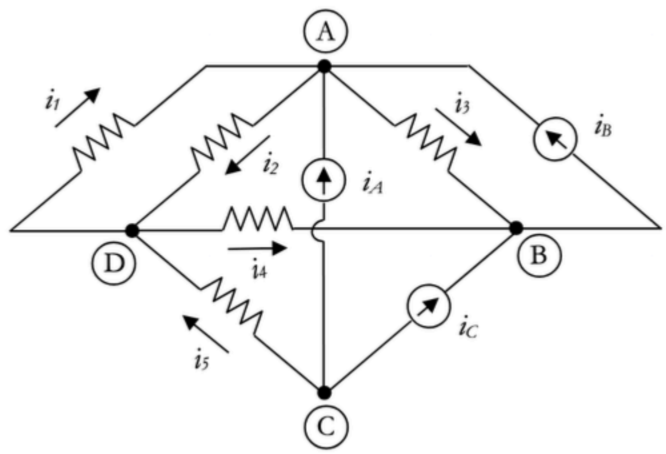
Example problem for demonstrating use of Microsoft Copilot. A circuit in the first laboratory activity was intentionally chosen for simplicity, with the instructor demonstrating use of both Microsoft Copilot and LTSpice, a widely used circuit simulation software.



Example homework problem wherein students were asked to identify and correct errors in the AI-generated solution. The solution, copied verbatim, was formatted to allow for easier grading.

6) (10 points) An ENGR 201 student used an AI tool to obtain KCL equations for a circuit on a homework problem. They copied the output from the AI tool on their homework submission and were surprised to not score full points. The circuit, prompt used, and the output from the AI tool are shown below. The output is reproduced with each line of the AI "solution" identified by a number (e.g. L1, L2, etc.). Identify and correct the error(s) in the AI "solution". **Include the line number with the error, explain the error and correct the error.** *For example: In lines L3 and L4, the KCL is incorrect. The correct equation is:* $i_A + i_1 = i_2 + i_3$.

Prompt: Write KCL equations at nodes A, B, C and D.



Output from the AI tool in response to the prompt	
I'll write each node's KCL using the arrows as shown in the figure (take currents with the same sign as their drawn arrows).	L1
You can use either form (all terms on one side = 0, or isolate one current).	L2
Node A (top): Current from the source into A (i_A, arrow upward into A) flows out through the three branches i_1,i_2,i_3, so:	L3
$i_A - i_1 - i_2 - i_3 = 0 \Leftrightarrow i_1 + i_2 + i_3 = i_A.$	L4
Node B (right): All labelled currents at B point into the node (by the arrows), so their algebraic sum is zero:	L5
$i_B + i_3 + i_4 + i_C = 0.$	L6
Node C (bottom): The branch current up the vertical (the same branch that carries i_A upward) plus the two currents leaving C along the diagonals give:	L7
$i_A + i_C + i_5 = 0 \Leftrightarrow i_A = -(i_C + i_5).$	L8
Node D (left): Currents leaving D are i_1 (up toward A) and i_4 (to the right); currents entering D are i_2 and i_5, so	L9
$i_1 + i_4 - i_2 - i_5 = 0 \Leftrightarrow i_1 + i_4 = i_2 + i_5.$	L10
Those four equations are the KCL equations at A, B, C and D (using the arrow directions shown).	L11