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Student-Driven AI Adoption: A Cross-Course Analysis of AI Tool Utilization and Perceptions in Electrical and Computer Engineering Education

Dr. Ahmed Dallal, University of Pittsburgh

Dr. Ahmed Dallal is an Associate Professor in the Department of Electrical and Computer Engineering at the University of Pittsburgh, where he has been a faculty member since 2017. His scholarly work spans two interconnected areas: engineering education research and biomedical signal and image processing. In education, Dr. Dallal investigates pedagogical innovations, including blended learning, active learning, and gamification, with a focus on improving student performance and engagement in ECE courses. In his technical research, his interests include biomedical signal processing, neural data analysis, machine learning, computer vision, and networked control systems. Dr. Dallal is an active member of ASEE, where he has served in multiple leadership roles in the New Engineering Educators Division, including Division Chair.

WIP Student-Driven AI Adoption: A Cross-Course Analysis of AI Tool Utilization and Perceptions in Electrical Engineering Education

Abstract

The integration of Artificial Intelligence (AI) tools into higher education represents a significant shift in how students engage with complex technical content. This work-in-progress study investigates student-driven adoption and utilization of AI tools across two electrical engineering courses: a sophomore-level Linear Circuits and Systems course (n=50) and a junior-level Linear Control Systems course (n=4). Through end-of-semester surveys administered in Summer and Fall 2025, we examined frequency of use, task-specific applications, perceived helpfulness, fact-checking behaviors, and integration opinions. Results reveal differential adoption rates (66% in Circuits vs. 100% in Control Systems) with students primarily employing AI for concept explanation (91% in Circuits, 75% in Control), generating practice problems (61% in Circuits), and homework assistance (52-75%). Perceived helpfulness was moderate to high across dimensions (M=2.97-4.12 on 5-point scale), with students rating understanding (M=4.12) highest in the Circuits course. Importantly, 79% of students reported frequent fact-checking behaviors. These findings provide empirical evidence for developing balanced AI integration frameworks that leverage benefits while maintaining pedagogical rigor and independent learning skills.

1. Introduction

The rapid emergence of large language models (LLMs) and generative AI tools has fundamentally transformed the educational landscape. Tools such as ChatGPT, Claude, GitHub Copilot, and specialized platforms like Wolfram Alpha have become ubiquitous among students, offering on-demand assistance with concept clarification, problem-solving, code generation, and content creation. This technological shift mirrors historical transitions in education, such as the introduction of calculators in mathematics education during the 1970s and the integration of internet search engines in the 1990s [1], [2]. Each of these innovations initially sparked debate about their impact on learning, with concerns about over-reliance and skill degradation eventually giving way to pedagogical frameworks that leverage these tools effectively while maintaining educational rigor [3].

In engineering education specifically, the stakes are particularly high. Engineering curricula demand mastery of complex mathematical models, abstract concepts, and sophisticated problem-solving skills. Students must develop not only technical knowledge but also critical thinking abilities, analytical reasoning, and professional judgment—skills that form the foundation of engineering practice. The introduction of AI tools that can generate solutions, explain concepts, and debug code raises fundamental questions: How are students actually using these tools? Do AI assistants support or undermine deep learning? What pedagogical interventions are necessary to ensure AI tools enhance rather than replace genuine understanding?

Despite the widespread availability and adoption of AI tools, empirical research examining how engineering students autonomously integrate these technologies into their learning practices remains limited. Most existing studies focus on controlled interventions where instructors explicitly integrate AI tools into coursework, or they examine student perceptions through hypothetical scenarios rather than actual usage patterns [4] – [8]. There is a critical need for research that captures organic, student-driven adoption—understanding not what instructors prescribe, but what students actually do when given autonomy in their learning process.

This study addresses this gap by investigating student-driven AI tool adoption and utilization across two electrical engineering courses at different levels: a sophomore-level Linear Circuits and Systems course and a junior-level Linear Control Systems course. Through comprehensive end-of-semester surveys, we examine several key dimensions of AI usage: frequency of use, specific tasks for which AI is employed, perceived helpfulness across different learning objectives, fact-checking and verification behaviors, challenges encountered, and student opinions on formal AI integration into coursework. Our comparative cross-course design allows us to explore how AI usage patterns may differ with course level and subject matter maturity.

2. Methods

2.1 Research Context and Participants

This work-in-progress study examines AI tool adoption and usage patterns across two electrical and computer engineering courses offered at the University of Pittsburgh. Both courses are required courses for the students in the electrical engineering major at the University of Pittsburgh. The first course, Linear Circuits and Systems, is a sophomore-level course that introduces students to fundamental circuit analysis techniques, including DC and AC circuit analysis, transient response, phasor domain analysis, and frequency domain concepts. This course serves as students' foundation in circuit theory and mathematical modeling within their major, typically taken in the first semester of sophomore year. The average enrollment is 55 students in the fall semester.

The second course, Linear Control Systems, is a junior-level course that builds on circuits and systems knowledge to explore feedback control theory, system stability, controller design, and MATLAB-based simulation. This course represents a more advanced application of engineering principles and requires integration of mathematical analysis with computational tools. The average enrollment in the summer semester is eight students.

The Linear Circuits course was offered in Fall 2025 with 50 (out of 58) students completing the end-of-course survey. The Linear Control Systems course was offered in Summer 2025 with 4 (out of 8) students responding to the survey. Neither course included formal integration of AI tools into the curriculum or assignments. Students' use of AI tools was entirely self-directed and autonomous, providing insight into organic adoption patterns rather than instructor-mandated usage. Course instructors neither explicitly encouraged nor prohibited AI tool usage, though standard academic integrity policies regarding plagiarism and unauthorized assistance remained in effect. This approach allowed us to capture authentic, student-driven AI adoption behaviors.

2.2 Survey Instrument

Data was collected through anonymous online surveys administered at the conclusion of each course. The survey instruments were designed to capture multiple dimensions of AI tool usage and student perceptions while minimizing respondent burden. Both surveys included similar core questions about AI usage, though with minor adaptations to reflect course-specific content (e.g., "control theory concepts" vs. "circuit analysis concepts").

The survey included the following key question domains:

1. AI Tool Usage: Binary question asking whether students used AI tools (e.g., ChatGPT, Copilot, Gemini, Wolfram Alpha, Claude) during the course, with an open-ended follow-up to specify which tools were used.
2. Frequency of Use: Ordinal scale measuring how often students used AI tools with five response options ranging from 'Never' to 'Very frequently (almost daily).'

3. Task-Specific Applications: Multiple-selection question identifying specific tasks for which students used AI tools. Options included: explaining course concepts, debugging/improving code, generating practice problems, summarizing lecture notes/textbooks, assisting with homework/labs, and understanding lab concepts. An 'other' option allowed write-in responses.
4. Perceived Helpfulness: Four 5-point Likert scale items (1 = Not at all helpful, 5 = Extremely helpful) assessing helpfulness for: (a) improving understanding of course concepts, (b) enhancing problem-solving skills, (c) saving time on assignments/labs, and (d) reliability of AI-generated explanations/code.
5. Fact-Checking Behaviors: Ordinal scale question asking how frequently students verified AI outputs against course materials or instructor guidance with five response options from 'Never' to 'Always.'
6. Challenges Encountered: Multiple-selection question identifying challenges including over-reliance, incorrect/misleading responses, difficulty formulating prompts, and ethical concerns, with space for additional challenges.
7. Integration Opinions: Five-point ordinal scale asking whether students believed AI tools should be formally integrated into the course, ranging from 'Definitely not' to 'Definitely yes.'
8. Open-Ended Comments: Free-response questions inviting additional reflections on AI's role in learning, study habits, and desires for instructor guidance.

The surveys were implemented using Qualtrics and were voluntary and anonymous to encourage honest reporting. Students were informed that responses would not affect course grades and that aggregate data would be used for research purposes. The Institutional Review Board deemed the study exempt as it involved routine educational assessment.

2.3 Data Analysis

Quantitative data from closed-ended questions were analyzed using descriptive statistics. For categorical and ordinal variables, we calculated frequencies and percentages. For Likert-scale items, we computed means and standard deviations. Given the small sample size in the Control Systems course, statistical significance testing between courses was not conducted. Instead, we present descriptive patterns and discuss substantive differences that may inform future hypothesis-driven research with larger samples.

For multiple-selection questions (tasks and challenges), we calculated response frequencies as both counts and percentages of students who used AI tools. This approach illuminates the prevalence of different usage patterns within the AI-using population. Open-ended responses were analyzed using thematic coding to identify recurring themes, representative examples, and insights about AI usage motivations and concerns.

2.4 Limitations

Several limitations should be considered when interpreting results. First, the Control Systems sample is small (n=4), limiting generalizability and precluding statistical comparison. Second, self-report data may be subject to social desirability bias or recall bias. Students might underreport AI usage if perceived as academically questionable or over-report if believed to be valued. Third, the cross-sectional design captures usage at semester's end, providing limited insight into temporal evolution of practices. Fourth, data come from two courses at one institution, limiting generalizability to other contexts. Fifth, we do not measure learning outcomes or correlate AI usage with academic performance; perceived helpfulness may not reflect actual learning impact. Finally, differential sample sizes between courses (n=4 vs. n=50) limit direct statistical comparison, though descriptive patterns remain informative.

3. Results

We present results organized by the key research questions: adoption rates, frequency of use, tasks for which AI is employed, perceived helpfulness, fact-checking behaviors, challenges encountered, and opinions on formal integration.

3.1 AI Tool Adoption Rates

AI tool adoption differed notably between courses. In the Control Systems course, all four students who completed the AI section reported using AI tools, representing a 100% adoption rate among respondents. In the Circuits course, 33 of 50 students (66%) reported using AI tools.

Students reported using a variety of AI tools. In the Control Systems course, students mentioned ChatGPT, Wolfram Alpha, and GitHub Copilot (specifically for MATLAB coding). In the Circuits course, ChatGPT and Claude were the most commonly mentioned tools, with some students also referencing Gemini and Wolfram Alpha. The diversity of tools suggests students are exploring various AI platforms to meet their learning needs.

3.2 Frequency of AI Tool Use

Among students who used AI tools, usage frequency varied considerably. In the Control Systems course, most students (75%) reported occasional use (approximately weekly), with one student (25%) reporting rare use. In the Circuits course, usage was more distributed: 45.5% used AI occasionally, 27.3% frequently, 15.2% rarely, and 9.1% very frequently (daily). Notably, in Circuits, approximately 36% of AI users employed these tools frequently or very frequently (multiple times per week or daily), suggesting substantial integration into their learning routines. Figure 1 visualizes these frequency distributions.

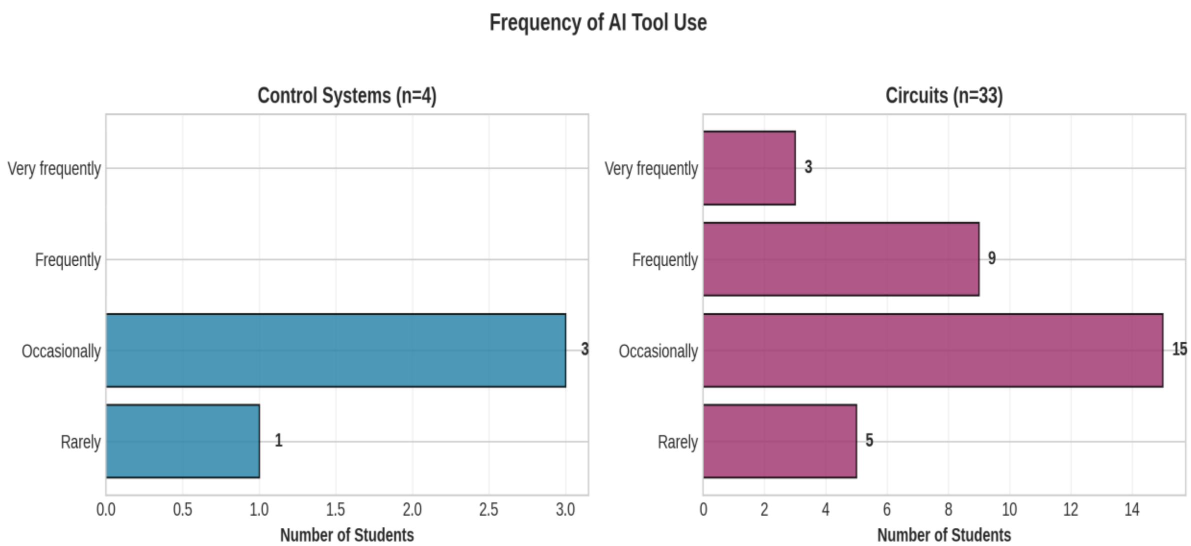

Figure 1. Frequency of AI Tool Use by Course

3.3 Tasks for Which AI Tools Were Used

Students used AI tools for multiple purposes. Table 1 presents the most common tasks, noting that students could select multiple options. Across both courses, explaining course concepts emerged as the most prevalent use case, with 91% of Circuits students and 75% of Control Systems students selecting this option. In the Circuits course, generating practice problems was particularly popular (61%), followed by homework/lab assistance and understanding lab concepts (each 52%). In Control Systems, debugging MATLAB code, homework assistance, and concept explanation were equally common (75% each). The substantial use for homework/lab assistance may include both problem-solving support and writing assistance. The latter represents a particularly sensitive application given the importance of technical writing skills in engineering practice.

Figure 2 compares usage across the three tasks common to both surveys. The data suggests students primarily view AI tools as learning supports for understanding concepts rather than as direct problem-solving replacements.

Table 1. Tasks for Which AI Tools Were Used

Task	Control	Circuits
Explaining course concepts	3 (75%)	30 (91%)
Debugging/improving code*	3 (75%)	N/A
Generating practice problems	N/A	20 (61%)
Homework/lab assistance	3 (75%)	17 (52%)
Understanding lab concepts	2 (50%)	17 (52%)
Summarizing notes/textbooks	N/A	12 (36%)

**MATLAB coding for Control Systems; this option not available in Circuits survey*

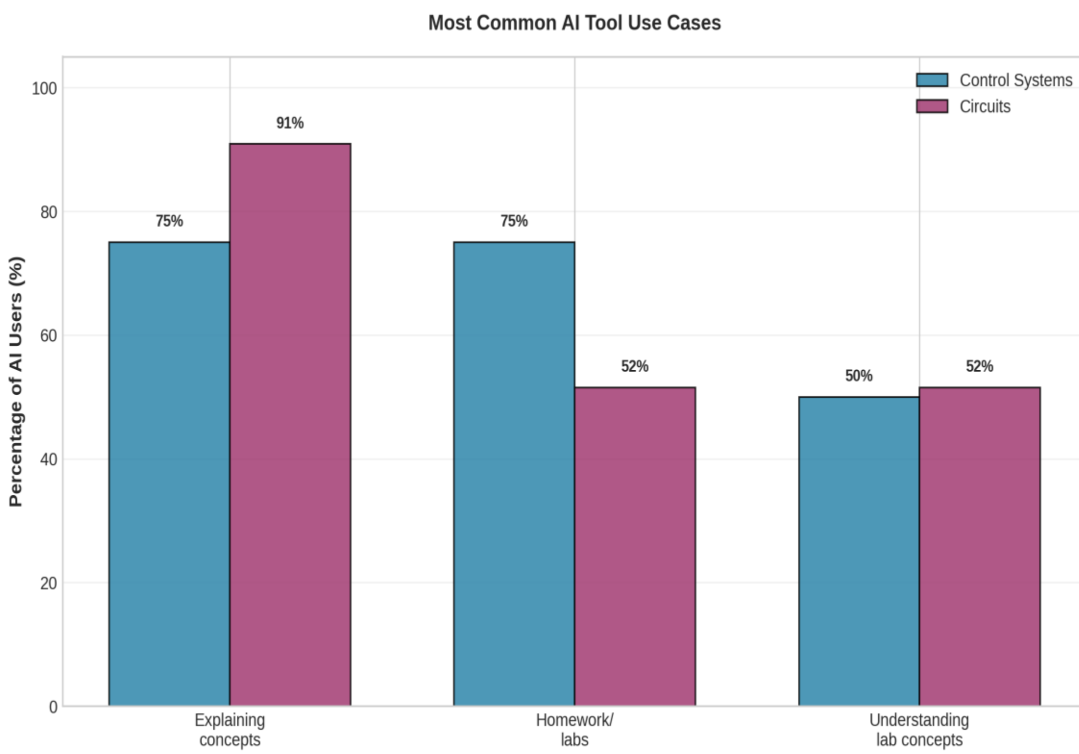

Figure 2. Comparison of Common AI Tool Use Cases

Qualitative comments from the Circuits course provided additional insight. One student noted: "I think it helped me develop a deeper understanding when I prompted it correctly. If I just asked it to help, then it wouldn't know what exactly I didn't understand. I used Claude to walk me through examples/help me understand topics by prompting it to 'guide me through by asking me questions'." This suggests some students have developed sophisticated prompting strategies to maximize learning benefits.

3.4 Perceived Helpfulness

Students rated AI helpfulness across four dimensions using 5-point Likert scales (1 = Not at all helpful, 5 = Extremely helpful). Table 2 presents means and standard deviations. Circuits students rated AI tools as most helpful for understanding concepts (M=4.12, SD=0.75), approaching "extremely helpful." This was notably higher than Control Systems students' rating (M=3.25, SD=1.48), though the large standard deviation in Control reflects greater variability in experiences.

Table 2. Perceived Helpfulness Ratings (1-5 scale)

Aspect	Control M (SD)	Circuits M (SD)
Understanding concepts	3.25 (1.48)	4.12 (0.75)
Problem-solving skills	3.00 (0.00)	3.50 (1.19)
Time savings	4.00 (0.71)	3.44 (1.24)
Reliability of outputs	3.25 (1.09)	2.97 (1.06)

Both groups gave moderate ratings for enhancing problem-solving skills (M=3.0-3.5), indicating perceived benefit but recognition that AI is not a complete solution.
Interestingly, Control Systems students rated time savings higher (M=4.00) than Circuits students (M=3.44), though both groups recognized efficiency benefits. Reliability ratings were the lowest across both courses (M=2.97-3.25), hovering near the midpoint. This suggests students are aware that AI-generated content requires verification and should not be accepted uncritically. Figure 3 provides a visual comparison of these helpfulness dimensions.

3.5 Fact-Checking Behaviors

An important dimension of responsible AI use is verification of AI-generated content. We measured the frequency with which students fact-checked AI outputs against course materials or instructor guidance. Encouragingly, no students in either course reported never fact-checking AI outputs. In the Circuits course, 79% of students reported frequent fact-checking behaviors (27% always, 52% often), with only 12% sometimes checking and 6% rarely checking. In Control Systems, 50% reported always or often fact-checking, while 50% sometimes checked. Figure 4 visualizes these distributions, revealing that most students engage in verification behaviors, though the consistency varies.

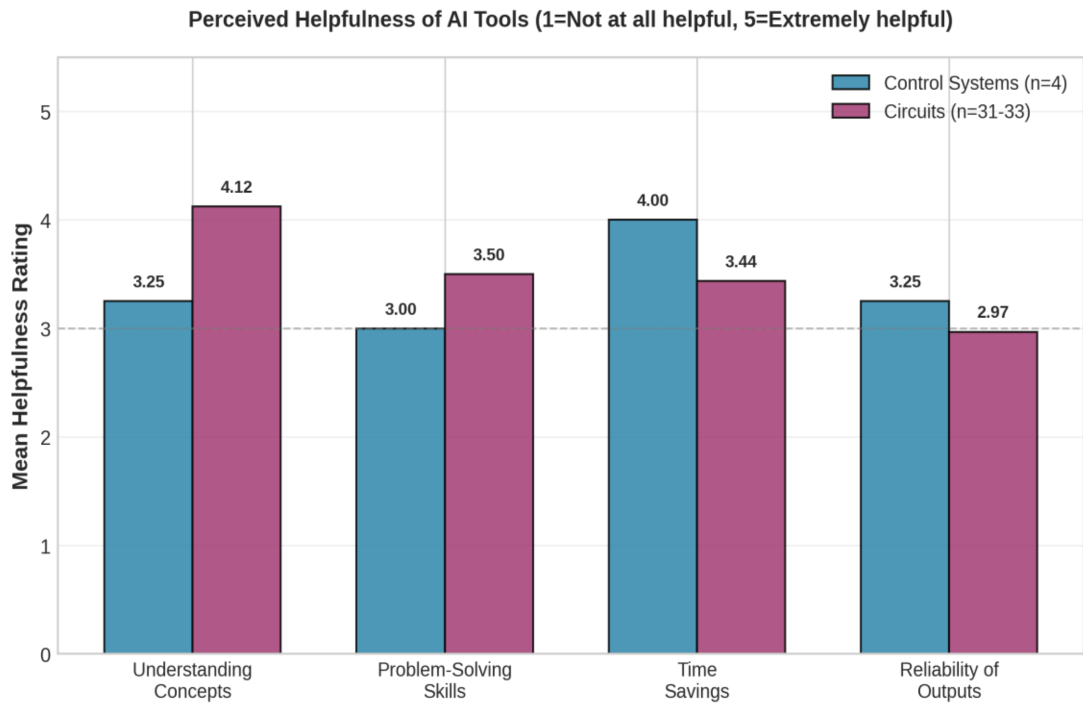

Figure 3. Perceived Helpfulness of AI Tools Across Dimensions

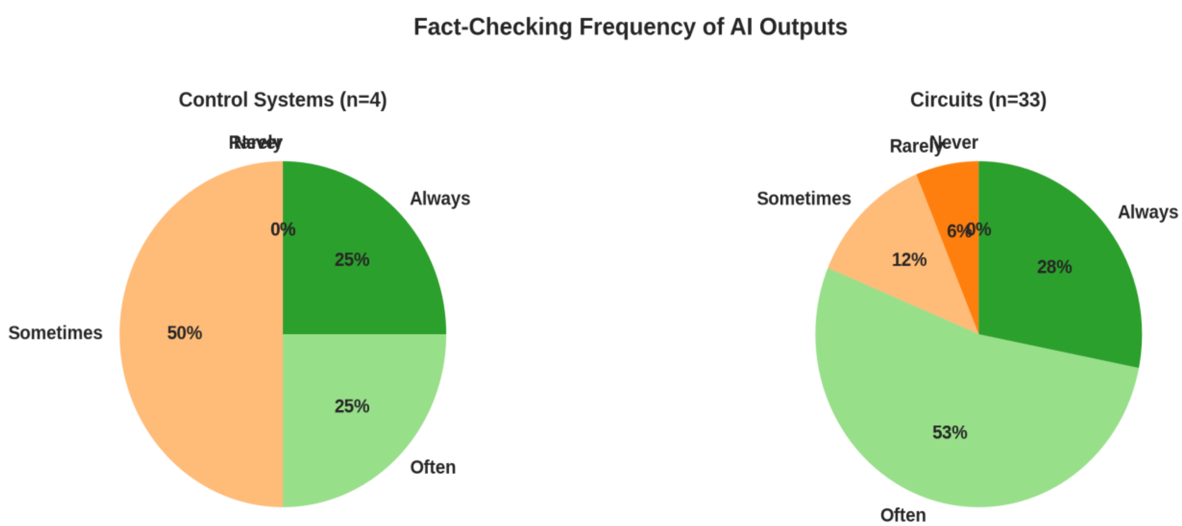

Figure 4. Fact-Checking Frequency by Course

One Circuits student commented on their iterative approach: "I often had to ask AI not to skip steps so that I could fully understand the method." This reflects metacognitive awareness and active engagement with AI as a learning tool rather than passive acceptance of outputs.

3.6 Challenges Encountered

Students identified several challenges when using AI tools. The most common challenges in both courses were incorrect or misleading AI responses (reported by 25% of Control students and multiple Circuits students) and difficulty formulating effective prompts. Ethical concerns about plagiarism and academic integrity were also mentioned by students in both courses. One Control Systems student expressed a fundamental concern: "How do I know they produce reliable information?"

In the Circuits course, additional qualitative comments revealed nuanced concerns. One student noted: "I don't like AI because I don't really think when using it and it over-takes my ability to learn." This self-awareness about potential over-reliance is notable and suggests some students are actively monitoring their engagement with AI tools to ensure they maintain independent learning skills.

3.7 Opinions on Formal AI Integration

Students were asked whether AI tools should be formally integrated into their courses. Opinions were mixed in both courses. In Control Systems, 50% were uncertain ("might or might not"), with 25% leaning positive and 25% leaning negative. In Circuits, 49% were also uncertain, 24% leaned positive, and 24% leaned negative. The mean opinion scores were nearly identical: 3.00 for Control Systems and 3.06 for Circuits on a 1-5 scale (where 3 represents "might or might not"). This uncertainty is visualized in Figure 5.

Qualitative comments provided additional context. Several Circuits students expressed desire for structured guidance, with 36% of AI users (12 students) responding "Yes, definitely" when asked if they would have liked more instructor guidance on effective and ethical AI use. One student elaborated: "It is similar to coding. When I did homework one I felt one of my answers was really wrong so I had ChatGPT do it and followed its steps and realized I did it right. If it is used as a check and not the teacher I think it is a very good tool." Another student thoughtfully noted: "The intentions behind using AI is ultimately up to the student themselves. Using AI as a supplemental

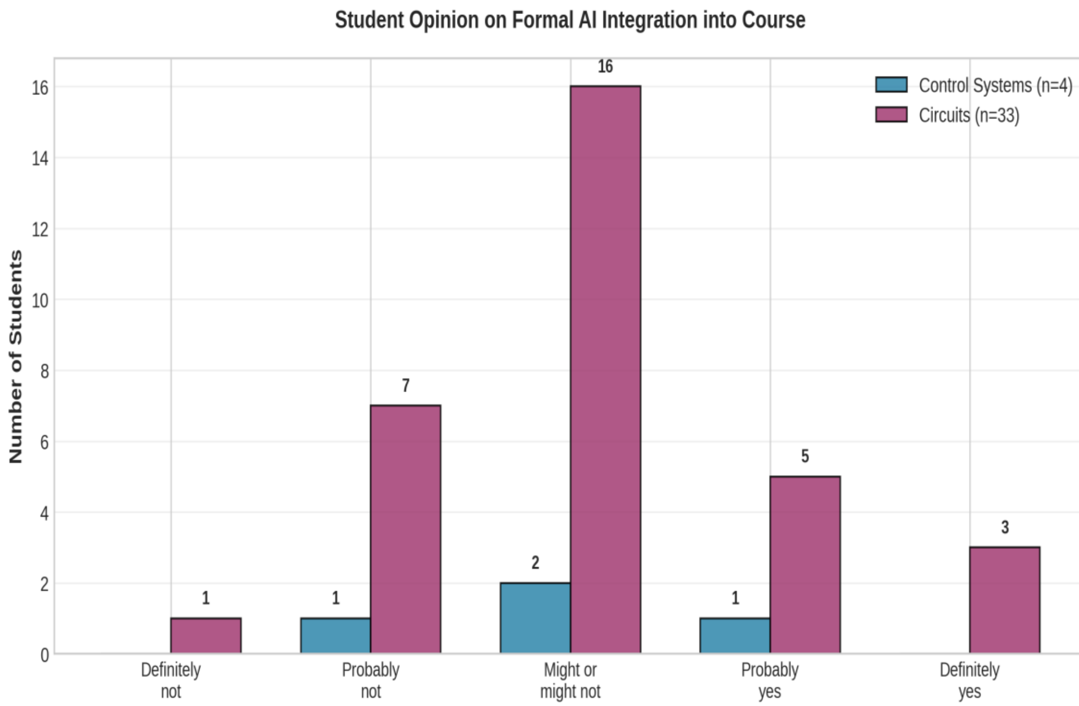

Figure 5. Student Opinions on Formal AI Integration

tool is how you get the most out of it in my opinion because this means that you have attempted to find a solution yourself first."

4. Discussion

This study investigated student-driven AI tool adoption across two electrical engineering courses, providing empirical evidence about organic usage patterns, perceived benefits, and challenges. The findings reveal a complex picture of AI integration into engineering education, with important implications for pedagogical policy and practice.

4.1 High Adoption and Frequent Use

The high adoption rate—specifically in Circuits—indicates that AI tools have become normalized in engineering students' learning practices. This widespread adoption occurred without instructor mandate or explicit integration into coursework, suggesting that students perceive genuine value in these tools. The 66% adoption rate in the larger Circuits sample aligns with recent surveys of undergraduate STEM students, which report adoption rates between 60-75% [9]. While the small Control Systems sample (n=4) precludes definitive conclusions, we observe some suggestive patterns worth noting for future investigation. The higher rate in Control Systems may reflect several factors: the smaller, self-selected summer course population; greater engineering maturity (junior vs. sophomore level); or the computational nature of control systems work with MATLAB, where coding assistants like GitHub Copilot are particularly relevant. If confirmed with larger samples, this pattern could suggest that more advanced students use AI more selectively and strategically rather than as a constant study companion. However, this interpretation remains speculative given our sample size limitations.

The frequency data reveal that AI use is not occasional for many students—approximately 36% of Circuits AI users employed these tools frequently or very frequently (multiple times weekly or daily). This suggests substantial integration into regular study routines rather than sporadic consultation during difficulty. This pattern parallels findings by Baidoo-Anu and Ansah [8], who documented daily AI use among approximately 40% of students across disciplines.

4.2 AI as Learning Support, Not Replacement

The task usage data suggest that students primarily employ AI tools to support learning rather than to bypass it. Explaining concepts was the dominant use case (91% in Circuits, 75% in Control), followed by generating practice problems (61% in Circuits). These applications align with constructivist learning principles—seeking alternative explanations, testing understanding through practice, and scaffolding complex material. This finding is encouraging and contrasts with some fears that students primarily use AI to generate assignment solutions without engagement.

However, the substantial use for homework assistance (52-75%) warrants attention. While AI can legitimately support homework—clarifying problem statements, checking approaches, debugging code—there is risk of dependence that undermines learning. The distinction between AI as a "tutor" versus a "solution generator" may be subtle and context-dependent. As one student noted, the tool can be valuable "if it is used as a check and not the teacher." This articulation captures an important pedagogical boundary: AI should verify rather than replace the student's problem-solving process.

The popularity of generating practice problems (61% in Circuits) is particularly noteworthy. This proactive learning behavior—seeking additional practice beyond assigned work—suggests students are using AI to extend their learning opportunities. This aligns with findings by Lo [11] that students value AI for its ability to generate customized practice materials, allowing them to target specific areas of difficulty.

4.3 Moderate Perceived Helpfulness and Reliability Concerns

Students' helpfulness ratings paint a nuanced picture. The high rating for understanding concepts in Circuits (M=4.12) suggests AI tools could provide alternative explanations and support conceptual learning. This is consistent with research by Sullivan et al. [4], who found AI chatbots effective for concept clarification in technical courses. However, the more moderate ratings for problem-solving skills (M=3.0-3.5) and notably lower ratings for reliability (M=2.97-3.25) indicate awareness of limitations.

The reliability concerns are particularly important. Students' recognition that AI outputs require verification demonstrates critical engagement rather than blind trust. This skepticism is well-founded given documented issues with AI "hallucinations" and errors in technical domains [13]. The fact that reliability received the lowest helpfulness ratings suggests students have encountered inaccuracies firsthand and adjusted their usage accordingly.

The variation between courses in perceived helpfulness—particularly the higher conceptual understanding rating in Circuits—may reflect several factors. The larger Circuits sample provides more stable estimates. Additionally, circuit analysis concepts may be more amenable to AI explanation than control theory abstractions, or the sophomore students may find AI particularly valuable when first encountering rigorous engineering analysis, while junior students have developed alternative learning strategies.

4.4 Encouraging Fact-Checking Behaviors

Perhaps the most encouraging finding is the prevalence of fact-checking behaviors. In Circuits, 79% of students reported frequent verification (always or often), with zero students reporting never checking. This suggests most students approach AI outputs with appropriate skepticism and engage in verification—precisely the behavior educators hope to encourage. This finding contrasts with concerns that students might uncritically accept AI-generated content, though it is important to note that self-reports of verification may overestimate actual behavior due to social desirability bias.

The fact-checking behaviors likely stem from several sources: students encountering errors that taught them to verify; awareness of academic integrity policies that emphasize personal understanding; and engineering culture that values accuracy and verification. The qualitative comment about asking AI not to skip steps suggests some students have developed metacognitive strategies to ensure deep understanding rather than surface-level acceptance of solutions.

However, the 50% "sometimes" rate in Control Systems and 18% "sometimes or rarely" rate in Circuits indicate that verification is not universal or consistent. This variability suggests opportunity for pedagogical intervention to strengthen verification habits and teach effective verification strategies.

4.5 Challenges and Concerns

Students identified three primary challenges: incorrect/misleading AI responses, difficulty formulating effective prompts, and ethical concerns. Each represents an important dimension for educational response.

The concern about incorrect responses reinforces the reliability findings and highlights the need for AI literacy. Students need to understand when and why AI systems make errors—such as in complex mathematical derivations or when asked to extrapolate beyond training data. Teaching students to recognize potential error patterns would enhance their critical evaluation capabilities.

Difficulty with effective prompting is a practical challenge that could be addressed through explicit instruction. Effective prompting is a skill that improves with practice and guidance [6]. Students who learn to provide context, specify desired depth, and iterate on prompts likely derive greater benefit from AI tools. The student who described asking AI to "guide me through by asking me questions" demonstrates sophisticated prompt engineering that transforms AI from answer-provider to Socratic tutor.

Ethical concerns about plagiarism and academic integrity reflect awareness of boundaries, though students may be uncertain about where those boundaries lie. The qualitative comment about over-reliance—"I don't really think when using it and it over-takes my ability to learn"—demonstrates remarkable self-awareness but also highlights a genuine risk. When AI tools are readily available, maintaining productive cognitive struggle requires intentionality. This echoes findings by Sanusi et al. [10] that bypassing struggle risks undermining the development of problem-solving expertise.

4.6 Ambivalence about Formal Integration

Student opinions on formal AI integration cluster around uncertainty. Approximately half of students in both courses selected "might or might not," with positive and negative leaners roughly balanced. This ambivalence likely reflects conflicting considerations: recognition of AI's utility balanced against concerns about over-reliance, equity, or changing academic expectations.

The desire for instructor guidance (expressed by 36% of Circuits AI users) suggests students want clarity about appropriate use and effective strategies. This represents an opportunity for faculty to provide scaffolding without mandating specific tools. Rather than prescriptive integration, instructors might offer guidance documents, example prompting strategies, discussion of limitations, and clear policies about acceptable use for different assignment types.

The student comment that "the intentions behind using AI is ultimately up to the student themselves" is philosophically interesting. While individual agency is important, education also involves developing judgment about appropriate tool use. The challenge is helping students internalize productive practices without micromanagement or prohibition.

4.7 Implications for Pedagogy

These findings suggest several implications for engineering educators. First, prohibition is likely ineffective given widespread adoption. Rather than banning AI tools, educators should acknowledge their reality and provide guidance for productive use. This parallels the eventual acceptance of calculators and internet search after initial resistance [1, 2].

Second, explicit instruction in AI literacy could enhance benefits and mitigate risks. This includes teaching effective prompting strategies, demonstrating verification techniques, discussing when AI is (and isn't) appropriate, explaining why AI makes certain errors, and modeling metacognitive practices like the "ask me questions" approach described by one student.

Third, assessment design matters. If AI can readily solve homework problems, educators might reconsider assessment formats. This could involve emphasizing in-class exams, requiring process documentation (showing work and reasoning), designing problems that require integration of multiple concepts, incorporating reflection components where students explain their problem-solving approach, or creating assignments where AI assistance is explicitly permitted and incorporated into learning objectives. Additionally, while our data focused primarily on concept explanation and problem-solving applications, an important consideration is the use of AI for report writing and technical documentation. Although this was not a primary focus of our survey questions, the substantial use of AI for homework/lab assistance may include writing components. This represents a particularly sensitive application, as technical writing is a core engineering competency. Using AI to generate reports without substantial student input could undermine development of critical communication skills, reduce knowledge consolidation that occurs through writing, and diminish students' confidence in their own technical communication abilities. This concern deserves careful attention in future research and in development of AI use guidelines. Instructors might address this by: (1) designing writing assignments that require personal reflection, iteration, and synthesis that AI cannot easily replicate; (2) explicitly distinguishing acceptable AI use (e.g., grammar checking, outline generation) from unacceptable use (generating full report text); (3) incorporating drafting processes that demonstrate student authorship; and (4) using oral presentations or defense of written work to verify understanding. Future surveys should include specific questions about AI use for technical writing to better characterize this application and its impacts.

Fourth, fostering metacognitive awareness helps students monitor their engagement. The student who recognized AI was "over-taking" their learning demonstrates valuable self-awareness. Instructors might prompt similar reflection through periodic check-ins, journaling about AI use, or class discussions about balancing efficiency with learning.

Fifth, the substantial use of AI for generating practice problems suggests opportunity for partnership. Instructors might explicitly encourage this use while teaching students to evaluate problem quality and difficulty, moving from instructor-as-sole-content-provider toward instructor-as-curator and guide.

4.8 Limitations and Future Research

The small sample in Control Systems (n=4) limits generalizability and precludes statistical comparison. Replication with larger samples across multiple sections and institutions is needed. The reliance on self-report data may not fully capture actual behavior—students may overreport desirable behaviors like fact-checking. Future research might triangulate surveys with learning analytics, assignment submissions, or think-aloud protocols during AI use.

Critically, this study does not establish causal relationships between AI use and learning outcomes. Students who use AI more or less frequently may differ in ways that independently affect performance. Future research should examine correlations between usage patterns and learning outcomes measured through concept inventories, exam performance, or retention of knowledge over time.

Longitudinal research tracking how AI usage evolves throughout a semester or across multiple courses would illuminate developmental patterns. Do students who initially over-rely eventually self-correct? How do usage patterns change as students gain experience? Understanding these trajectories could inform when and how to intervene.

Finally, controlled studies comparing learning outcomes between students receiving AI literacy instruction versus those without such guidance could establish effectiveness of specific pedagogical interventions. Similarly, experiments with different AI integration approaches (e.g., explicitly AI-assisted assignments versus AI-prohibited assignments versus neutral stance) could identify which strategies optimize learning.

5. Conclusions

This study provides empirical evidence about how electrical engineering students organically adopt and utilize AI tools when given autonomy. The findings reveal high adoption rates (66-100%), frequent use (36% of Circuits AI users employed tools multiple times weekly or daily), and primarily learning-oriented applications focused on understanding concepts, generating practice, and obtaining alternative explanations.

Importantly, students demonstrate awareness of AI limitations—they rate reliability moderately, report frequent fact-checking behaviors, and articulate concerns about over-reliance and accuracy. These findings are encouraging, suggesting students are engaging critically rather than accepting AI outputs uncritically.

However, challenges remain. Students struggle with effective prompting, encounter incorrect responses, and express ethical concerns about appropriate boundaries. The variation in fact-checking frequency and the acknowledgment that AI sometimes "over-takes" learning indicate risks that warrant attention.

The ambivalence about formal integration—with roughly half of students uncertain—combined with expressed desire for guidance suggests an opportunity for educator intervention. Rather than mandating or prohibiting AI tools, faculty can acknowledge their reality, provide scaffolding for effective use, and help students develop judgment about appropriate application.

This study contributes to the growing literature on AI in engineering education by documenting actual usage patterns in organic, non-mandated contexts. The cross-course comparative design illuminates how adoption and use vary with course level and content. The findings suggest that blanket prohibitions are likely ineffective and potentially counterproductive given widespread adoption. Instead, thoughtful integration frameworks, that acknowledge AI's reality, provide explicit guidance, redesign assessments to maintain rigor, and foster metacognitive awareness may better serve student learning.

References

[1] G. H. Wheatley, "Calculator Use and Problem Solving Performance," *Journal for Research in Mathematics Education*, vol. 11, no. 5, pp. 323-334, 1980.

[2] K. Ruthven and S. Hennessy, "A Practitioner Model of the Use of Computer-Based Tools and Resources to Support Mathematics Teaching and Learning," *Educational Studies in Mathematics*, vol. 49, no. 1, pp. 47-88, 2002.

[3] M. J. Metzger, A. J. Flanagin, and R. B. Medders, "Social and Heuristic Approaches to Credibility Evaluation Online," *Journal of Communication*, vol. 60, no. 3, pp. 413-439, 2010.

[4] M. Sullivan, S. Kelly, and P. McLaughlan, "ChatGPT in Higher Education: Considerations for Academic Integrity and Student Learning," *Journal of Applied Learning and Teaching*, vol. 6, no. 1, pp. 1-10, 2023.

[5] E. Kasneci et al., "ChatGPT for Good? On Opportunities and Challenges of Large Language Models for Education," *Learning and Individual Differences*, vol. 103, p. 102274, 2023.

[6] P. Denny, V. Kumar, and N. Giacaman, "Conversing with Copilot: Exploring Prompt Engineering for Solving CS1 Problems Using Natural Language," in *Proc. 54th ACM Technical Symposium on Computer Science Education*, Toronto, Canada, 2023, pp. 1136-1142.

[7] M. Montenegro-Rueda et al., "Impact of the Implementation of ChatGPT in Education: A Systematic Review," *Computers in Human Behavior*, vol. 153, p. 108092, 2024.

[8] D. Baidoo-Anu and L. O. Ansah, "Education in the Era of Generative Artificial Intelligence (AI): Understanding the Potential Benefits of ChatGPT in Promoting Teaching and Learning," *Journal of AI*, vol. 7, no. 1, pp. 52-62, 2023.

[9] X. Wang, D. Guo, and C. Zhang, "Understanding STEM Students' Perceptions and Adoption of AI Tools for Learning," *Education and Information Technologies*, vol. 29, no. 2, pp. 1847-1871, 2024.

[10] I. T. Sanusi et al., "Generative Artificial Intelligence in Engineering Education: A Systematic Review," *IEEE Access*, vol. 11, pp. 115902-115918, 2023.

[11] C. K. Lo, "What Is the Impact of ChatGPT on Education? A Rapid Review of the Literature," *Education Sciences*, vol. 13, no. 4, p. 410, 2023.
[12] G. Cooper, "Examining Science Education in ChatGPT: An Exploratory Study of Generative Artificial Intelligence," *Journal of Science Education and Technology*, vol. 32, no. 3, pp. 444-452, 2023.
[13] H. Alkaissi and S. I. McFarlane, "Artificial Hallucinations in ChatGPT: Implications in Scientific Writing," *Cureus*, vol. 15, no. 2, p. e35179, 2023.
[14] D. R. E. Cotton, P. A. Cotton, and J. R. Shipway, "Chatting and Cheating: Ensuring Academic Integrity in the Era of ChatGPT," *Innovations in Education and Teaching International*, vol. 61, no. 2, pp. 228-239, 2024.
[15] D. Yan et al., "Equity, Access, and Ethics in AI-Enhanced Education," *International Journal of Artificial Intelligence in Education*, vol. 34, no. 1, pp. 89-112, 2024.