Integrating AI-Assisted Learning Analytics for Personalized STEM Instruction

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Abstract
Generative artificial intelligence (GenAI) tools such as ChatGPT and Copilot are increasingly shaping how engineering students approach coursework, study routines, and conceptual learning. This study investigates undergraduate engineering students' AI tool usage patterns and perceptions of AI-assisted learning, with an emphasis on learning support, critical thinking concerns, trust, and responsible use. Survey data were collected from 185 engineering students across multiple majors and academic levels. Descriptive analysis examined AI use frequency, purposes for AI use, and item-level attitudes measured using Likert-scale questions. A Composite AI Learning Attitudes Index was constructed from four aligned perception items, with reliability assessment performed using Cronbach's alpha. Inferential testing included one-way ANOVA to compare composite attitudes across AI use frequency groups and multiple linear regression controlling for academic characteristics. Results indicate that AI tool use is widespread, with most students reporting at least occasional usage, primarily for homework support and exam preparation. Students generally agreed that AI tools improve understanding of course concepts, while many also expressed concern that overreliance could weaken critical-thinking skills. Trust in AI accuracy and ethical reliability remained moderate to low; however, strong support was observed for responsible AI integration in coursework. ANOVA and regression results showed that AI use frequency was a significant predictor of composite attitudes, with frequent users reporting substantially higher overall AI learning attitude scores than non-users. Findings suggest that engineering programs should adopt structured strategies for responsible GenAI integration that emphasize verification, critical thinking reinforcement, and AI literacy to support learning outcomes.

Keywords: AI in education, learning analytics, personalized learning, student engagement, engineering pedagogy, engineering students, generative AI tools, student perceptions, critical thinking, responsible AI use, educational technology, AI-enhanced learning

Introduction

The rapid emergence of generative artificial intelligence (GenAI) tools has introduced a major shift in how students engage with learning materials, complete assignments, and develop conceptual understanding. Since the public release of ChatGPT in late 2022, large language model (LLM)-based tools have become widely accessible and increasingly embedded in everyday academic workflows [1]. This rapid adoption has raised important questions for higher education, including how AI influences learning strategies, academic integrity, and student development of core skills such as engineering judgment and critical thinking. Recent engineering education research confirms that GenAI adoption is not theoretical or future-facing; it is already occurring at scale and has become relevant across multiple course contexts and instructional levels [2], [3], [4].

Within engineering education, this shift has heightened interest in understanding not only whether students use AI tools, but also how they use them and the attitudes they hold toward these tools. Engineering programs place strong emphasis on the development of structured problem-solving, conceptual reasoning, and evidence-based decision-making. These competencies rely on students' ability to critically interpret information, evaluate alternatives, and justify conclusions skills widely recognized as essential learning outcomes in higher education and workforce preparation [5], [6]. While GenAI tools may support student learning by providing explanations, examples, and scaffolding for complex material, concerns remain that overreliance may reduce students' independent reasoning or displace essential cognitive struggle that supports long-term learning. The challenge for educators is thus not merely technological, but pedagogical: institutions must determine how to integrate AI tools in ways that preserve academic rigor, foster critical thinking, and promote responsible use.

In response to these challenges, engineering educators and researchers have begun investigating students' perceived benefits, risks, and behaviors surrounding GenAI tools. Prior findings suggest that students often view AI as valuable for increasing efficiency, generating explanations, and supporting self-paced learning, while simultaneously expressing uncertainty regarding trustworthiness, accuracy, ethics, and appropriate boundaries for tool use in graded work [2], [7]. Further, emerging research on GenAI and higher education highlights the importance of clear policy guidance, transparency, and instructional designs that treat AI not as a replacement for learning but as a tool requiring critical evaluation [8]. Collectively, these studies point to a growing need for empirical evidence on student AI use behaviors and attitudes, particularly within engineering contexts where mastery of reasoning and accountability are central.

Despite the increasing prevalence of GenAI tools, significant gaps remain in the evidence base. First, engineering programs vary widely in how GenAI is addressed in coursework, ranging from prohibition to full encouragement of use, creating inconsistent student experiences across courses and instructors. Second, many current studies focus either on tool usage rates or isolated perceptions without linking usage frequency to multi-dimensional attitudes. Third, few studies provide quantitative models that allow educators to identify behavioral patterns associated with more favorable attitudes toward responsible AI use. Addressing these gaps is essential for developing AI-informed learning interventions and establishing pedagogical approaches that balance innovation with student learning outcomes.

To contribute to this emerging body of research, the present study examines undergraduate engineering students' engagement with AI-based tools and their perceptions of AI's role in learning. Using a survey-based dataset (N = 185), this paper evaluates (1) student frequency of AI tool use for coursework, (2) perceptions of AI's impact on understanding course concepts, (3) concerns about potential impacts on critical thinking, (4) trust in AI accuracy and ethics, and (5) support for responsible use of AI in engineering education. Findings from this study aim to inform engineering education practice by providing evidence on how students currently perceive and engage with GenAI tools and to support development of structured instructional guidance that promotes ethical and responsible AI use in coursework.

Literature Review

General Perspectives on the Utilization of Artificial Intelligence in STEM Education

The prospect of implementing artificial intelligence into the education system as an additional resource has garnered much publicity, both positive and negative. In the minds of many, artificial intelligence is a viable, dependable, and easily accessible tool. Yeung et al. [8] performed a study to identify university students' varying perspectives and perceptions regarding the emergence of Artificial Intelligence (AI). The conclusion from that study was that both undergraduates and graduates generally have positive perceptions of Generative Artificial Intelligence (GenAI), such as ChatGPT, Gemini, Claude, etc., and recognize the potential benefits of using GenAI in academic and research-related activities. For example, they recognized that GenAI could assist them with finding relevant research materials efficiently, enhance overall learning and research experiences, improve the quality of their writing, and assist in summarizing informational content [9], [10]. Bernabei et al., who conducted a study examining the use of AI among university students, made a similar observation. They found that students perceived GenAI (in the case of this study, ChatGPT) as reliable, highlighting benefits such as enhancing performance by accelerating the completion of assignments, enriching the teaching process, and providing support in essay and report writing [11]. University students hold AI in high regard, as it allows them to accelerate processes such as information gathering and assignment completion [4].

Much like university students, professors, and faculty, they have a high regard for AI. Schmidt et al. recently conducted a study to evaluate the potential integration of AI into higher education and examine students' and faculty's perceptions of this integration. They discovered that the majority of faculty agreed that integrating AI into education is a transformative development that offers significant benefits for both educators and learners. The faculty in this study expressed high expectations for AI, regarding it as the future of education, likely to have as great of an impact as Microsoft Office and calculators were in the past [12]. Faculty and educators from this study seem to understand the numerous benefits and opportunities for growth that artificial intelligence can provide. Prilip et al. executed a study to determine perceptions of GenAI from the standpoint of professors/educators. They arrived at a similar conclusion to Bernabei et al., finding that educators believed a professional use of AI could be highly beneficial, as it could assist with responsibilities such as organizational tasks, lesson planning, materials preparation, and assessment [13]. Avci et al., who recently conducted a study to examine STEM educators' perspectives on the proficiency and challenges of implementing AI, expand more on the previous ideas. They discovered that educators recognized AI as a potential "cognitive aid" that could support student understanding of complex topics and could simplify/alleviate the need to perform "routine tasks" [14].

Though there are many benefits to incorporating AI into the education system, one concern that has been brought to light is the fear that this emerging technology will fuel the populace's already growing sense of dependency on it. Schmidt et al. highlights this concern in their study, noting that faculty at the university expressed concern about overreliance on AI tools. They feared that such overreliance could lead to a decline in human skills and critical thinking abilities, creating an overdependence on AI, which could potentially alter their mentality and reduce their thinking and problem-solving capabilities [12]. Prilip et al. shared the same concern, believing that the increased reliance on GenAI could hinder people's abilities to solve problems independently, think critically, and retain core academic skills [13]. Shen et al. performed a study to investigate teachers' perspectives on artificial intelligence. They discovered that, although teachers did acknowledge the benefits of this software, teachers emphasized the need for students to retain autonomy and control over how they applied the software [15].

Another fear and concern that should be highlighted is the idea that artificial intelligence will reduce possible job opportunities for students. Blake et al. conducted a survey to determine perceptions of artificial intelligence within the engineering field and found a growing concern about a possible decrease in job opportunities for engineers, as AI increases the productivity of engineers already in the field. Consequently, this increased productivity will likely decrease the salaries of both future and current engineers [16]. AI's capacity and capability to work indefinitely, without rest, provides concern for those seeking employment, as this ability will result in fewer employment opportunities [12]. Grunhut et al., who sought to evaluate AI's influence on medical education, agreed with this assessment, remarking that emerging technologies such as AI could potentially disrupt labor markets that are traditionally maintained through educational programs, which teach the necessary skills for the career being pursued [17].

Another concern regarding the implementation of artificial intelligence is the ethical issues surrounding this emerging technology. Zhuang et al. discussed the ethical concerns and considerations regarding artificial intelligence, noting the need for fairness, accountability, data transparency, data privacy, and data interpretability when handling this emerging technology [18]. Beege et al., who sought to evaluate the extent to which STEM educators in Germany assess the benefits and risks of GenAI (notably, ChatGPT), highlighted similar ethical and legal concerns to Zhuang et al. Some concerns included: privacy, copyright, illegal content or instructions, students using AI for deception and manipulation (e.g. plagiarism), and privacy [19]. Dwivedi et al. assessed the potential impacts of artificial intelligence and remarked that individuals and organizations can express concerns and a lack of trust in AI systems, notably the ethical dimensions of these systems and their use of shared data. The ethical dimensions and issues in question might include: the greater use of artificial intelligence, data sharing issues, inoperability of systems, and possible exhibition of discrimination [20]. Valeri et al., seeking to explore how students experience GenAI tools such as ChatGPT, also observed AI's troublesome 'black box' nature [21]. Setting guidelines to implement artificial intelligence more effectively and ethically will significantly reduce the negative perceptions surrounding artificial intelligence.

Limitations of the Implementation of Artificial Intelligence

Artificial intelligence has great potential to achieve great things, but in its current state, it still faces many limitations that hinder it from realizing its full potential. Inaccurate information generated by generative artificial intelligence software is one of the many things that hold artificial intelligence back from being a reliable tool. Safitra et al. conducted a literature review to determine the usefulness of artificial intelligence across various areas. They highlighted the possibility that artificial intelligence could produce incomplete, incorrect, or unrepresentative data if it was fed such data, underscoring an important integrity issue related to the software's application. To counteract such possibilities, it is crucial to employ procedures to properly acquire, clean, and manage the data fed to the model [22]. De Moura Oliveira and Vrančić evaluated the use of Generative Pre-Trained Performers (GPTs) in control engineering education and came to a similar conclusion. They concluded that the answers provided by GPTs could not yet be trusted, as hallucinations could occur, leading to incorrect answers being displayed to users. Németh et al., who also sought to evaluate the use of artificial intelligence in higher education, described hallucinations as a condition where Large Language Models (LLMs) suffer from data obsolescence, costly retraining, and the generation of factually incorrect information. de Moura Oliveira and Vrančić emphasized the need for human oversight and double-checking the information being distributed [23], [24].

Another limitation that could hold back artificial intelligence is the need to change the education system to fully implement it into certain curricula. For example, it would take a sizable quantity of change within medical education to accommodate the implementation of artificial intelligence, as a major overhaul to this education system would be very difficult. Significant curricular reform for medical education faces many limiting factors, including traditional, deeply embedded values and changes to the accreditation process [17]. Pino Tarragó et al., who conducted a study analyzing the integration of artificial intelligence into civil engineering education, make a similar observation. He remarks that such software would experience limited, fragmented integration in engineering programs, since the traditional curriculum structure emphasizes “technical content” over “broader human capabilities” [25].

The last limiting factor to consider is the people’s trust in artificial intelligence. While artificial intelligence offers many benefits, the lack of trust in the software’s output leaves many skeptical about its capabilities. Gültekin and Kavak aimed to uncover the anxieties about artificial intelligence among academic librarians. They discovered that librarians feared the possibility that such technologies would become smarter than humans and replace people in the workforce [26]. Although they admitted that the study was limited due to its only covering the anxieties of academic librarians, it would not be a stretch to say that their fears and concerns are shared among teachers, researchers, and students alike. Besides concerns about job security for humans, risks such as privacy, security, and data accuracy might also lead many to doubt the effectiveness of artificial intelligence in education [15], [22]. Lyu et al. reached a similar conclusion in their quantitative study. They discovered that a large majority of instructors prohibit the use of GenAI, which indicated a lack of trust in AI due to concerns regarding academic integrity and rising uncertainty/confusion on how to manage “AI-assisted assessment.” [27]. Vega-Rebolledo et al. identify another component that can raise doubt among the public: the lack of transparency and interpretability in LLMs. They explain that many algorithms have the common characteristic of being “black box,” meaning that these models lack transparency to show the user what’s happening as information is generated and lack explainability/interpretability to assist the user in understanding the information displayed [28]. Oliveira et al. argue that, given the known limitations of GenAI, it is imperative that students, whether now or later in their careers, use their “domain-specific knowledge and skills” to guide AI towards outputs of improved, reliable quality [29]. This emerging technology has much to offer, but it will not amount to much without support and trust from the individuals using it.

Implementation Methods and Applications

Artificial intelligence has great prospects and significant potential, but it is imperative that this emerging technology be implemented correctly. Implementing it as such will increase its effectiveness twofold and elicit more positive appraisal from students, professors, and researchers. Some applications and implementations of artificial intelligence into an academic environment would include office applications, coding platforms (e.g., W3Schools, Bubble), diagramming tools (e.g., draw.io, Lucidchart), and Learning Management Systems (LMS) (e.g., MindTap, MyLab, Nearpod), tools in which faculty reported utilizing for the purpose of enhancing teaching, learning, and even professional tasks [12]. These were the tools the teachers/instructors reported using to increase student engagement.

Going beyond simply listing apps powered by artificial intelligence and the functions they offer, generative artificial intelligence can be used to create personalized experiences that foster a richer learning experience outside the classroom. This technology can be used to develop realistic, immersive learning simulations that help students gain a deeper understanding of the material they are covering. Asking a generative artificial intelligence like Google Gemini or ChatGPT to walk the student through a problem step by step until they understand the material would prove quite beneficial. Generative artificial intelligence can produce interactive educational content that might not be displayed in textbooks or taught in lectures, which can help to reel in the students' interest and encourage them to engage more actively in the learning process [9].

Utilizing artificial intelligence as a tutor of sorts opens the possibility for students to acquire more knowledge on the topic they're studying, learning much more quickly from the chatbot compared to performing multiple Google searches. Tian and Zheng supported and highlighted this in their study, noting that artificial intelligence functions as a tutor, student and/or peer in education, providing the user with "cognitive guidance" and "affective support" to help students with the development of higher-order skills (i.e. the "4C" skills: creativity, critical-thinking, communication skills and collaboration), accelerating the process [30]. Additionally, the availability of artificial intelligence simplifies the process for a student seeking help outside the classroom, as they (or the professor) might not be able to meet during the professor's office hours due to a lack of time overlap. Wang et al., who conducted a study to investigate the use of this emerging technology for "feature engineering" education, found that artificial intelligence is used by professors and students as an assistant to help complete administrative tasks and understand difficult concepts more easily. They believe that this emerging technology is set to completely transform the education sector through adaptive learning systems or to improve existing education systems [31].

Another possible way to implement AI in higher education is to develop an AI-based predictive model that will help. Kanchon et al. sought to devise an effective method for determining a learner's preferred style of learning [32]. Shoaib et al. devised a similar idea to Kanchon et al., although Shoaib et al. sought to incorporate AI into "Campus Management Systems (CMSs)" for the purpose of predicting student success, automating the grading process, predicting student risks, and predicting possible graduation retention or dropouts [33]. Artificial intelligence could also be used to support those with disabilities [34]. Zhao et al., who sought to discuss the implementation of AI for students with disabilities, highlighted potential ways that AI could improve inclusivity and capabilities for students with disabilities, such as reading, writing, social engagement, and teaching [35].

Outside of academia, artificial intelligence also has significant applications in research. Artificial intelligence can be utilized to gain more perspectives on any complex topic being discussed, deepening students' understanding and enriching the students' quality and process of researching [12]. O'Connor et al. discussed possible ways artificial intelligence could be used in research and explained that it currently assists researchers in quickly reviewing literature, paraphrasing content from articles, citing sources, etc. These capabilities can assist researcher's streamline and simply the research process since it has the capacity to summarize articles, gather data, and assess information [36]. Wang et al., who recently conducted a literature review of the application of artificial intelligence in higher education teaching, identify several potential future applications in research. They believe that future research should focus on constructing and developing "GAI-based Supplementary Assistant tools" to enhance artificial intelligence's potential for data mining and prediction [37].With the assistance of artificial intelligence, researchers can complete tasks more effectively and efficiently.

Table 1 Summary of Literature on Artificial Intelligence in STEM and Higher Education

Theme	Authors	Focus Areas	Methods or Data	Key Findings
General Perspectives on the Implementation of Artificial Intelligence	Yeung et al. (2025)	Student perceptions on Generative Artificial Intelligence (GenAI)	Case study (Hong Kong)	Students had mostly positive perceptions of implementing artificial intelligence into education but recognized some potential downsides and limitations.
	Bernabei et al. (2023)	The use of Large Language Models (LLMs) in engineering education	Case study	Students generally perceived generative artificial intelligence as useful for academics and research.
	Schmidt et al. (2025)	Perceptions regarding integration the integration of AI in higher education	Qualitative Research	Professors generally had positive perceptions of (and even high expectations for) artificial intelligence, but, like the students, recognized potential concerns.
	Prilop et al. (2025)	Perceptions of GenAI in teacher education	Mixed methods	Professors/Educators believed professional usage of artificial intelligence would prove to be beneficial
	Shen et al. (2025)	Perspectives surrounding AI in education	Case study	Professors emphasized a need for students to retain autonomy and remain in control.
	Blake et al. (2021)	Artificial intelligence and engineering	Survey	Those within the engineering field expressed growing concerns for a possible lack of career opportunities.
	Grunhut et al. (2022)	Potential prospects of implementing AI in education	Literature review	Artificial intelligence has the potential to disrupt labor markets.
	Zhuang et al. (2025)	Ethical considerations regarding AI being used by instructors	Systematic review	Ethical considerations (e.g. data transparency and privacy) should be accounted for when utilizing artificial intelligence
	Dwivedi et al. (2021)	Multidisciplinary perceptions on artificial intelligence	Mixed methods (literature review and study)	Individuals and organizations can express a lack of trust in AI systems.
Limitations of the Implementation of Artificial Intelligence	Safitra et al. (2024)	Advantages and drawbacks of artificial intelligence in various fields	Literature review	Artificial intelligence can generate incorrect, biased, and/or incomplete data.
	de Moura Oliveira and Vrančić (2024)	Evaluation of Generalized Pre-trained Transformers in engineering education.	Literature review	Information generated by artificial intelligence cannot yet be fully trusted and requires human oversight and verification.
	Németh et al. (2025)	Exploration and use of artificial intelligence as a tutor	Pilot study	Artificial intelligence can hallucinate (i.e. have data incorrectness and obsolescence).
	Grunhut et al. (2022)	Challenges of implementing artificial intelligence into medical education	Literature review	It can be costly to implement AI because of the amount of effort it would take to completely change the education system.
	Pino Tarragó et al. (2025)	Integration of artificial intelligence	Mixed methods (study and qualitative data analysis)	The traditional structuring of the engineering education system can lead to a limited and fragmented integration of artificial intelligence.

	Gültekin and Kavak (2025)	Anxieties regarding artificial intelligence	Quantitative data analysis study	Librarians feared that AI would replace humans in the workforce.
	Shen et al. (2025)	Teacher perceptions regarding artificial intelligence in education	Mixed methods (qualitative and quantitative data analysis, and case study)	Risks such as lack of data privacy, security, and data accuracy might incur people's doubt in artificial intelligence.
	Vega-Rebolledo et al. (2025)	Explainable artificial intelligence for understanding academic success	Literature review	AI's characteristic of being a "black box" (i.e. lacking transparency) and lacking explainability can lead to a lack of trust from the populace.
Implementation Methods and Applications	Schmidt et al. (2025)	Strategies for AI integration into academia	Qualitative Research	Professors and faculty have found and utilized many different software that have incorporated artificial intelligence.
	Yeung et al. (2025)	Effect of artificial intelligence on learning and research practices/methods	Case study (Hong Kong)	Artificial intelligence can be utilized to increase student engagement in the learning process.
	Tian and Zheng (2025)	Artificial intelligence and its impact on students' 4C skills	Meta-analysis	Artificial intelligence can potentially serve as a tutor, helping students in the development of higher-order skills.
	Wang et al. (2025)	Artificial intelligence enhancing academic success and	Study and correlation analysis	Professors and students use artificial intelligence as an assistant.
	O'Connor et al. (2025)	Research applications of artificial intelligence	Qualitative data analysis	Artificial intelligence can streamline and simplify the research process.
	Wang et al. (2025)	Artificial intelligence enhancing the research process	Systematic literature review and study	Researchers believe that future research should focus on generative artificial intelligence-based Supplementary Assistant tools.

Data and Methodology

Data Source and Study Context

This study uses primary survey data from undergraduate engineering students to examine perceptions and usage patterns of AI-based tools (e.g., ChatGPT, Copilot) in engineering coursework. The survey includes student demographic/academic context variables (major, academic level, engineering course load), AI usage frequency, AI use purposes, four Likert-scale attitude items, and an open-ended item capturing qualitative reflections on how AI has changed learning and studying behaviors. The intent of the dataset is to support an evidence-based understanding of students' current engagement with AI tools and how these tools may influence learning, critical thinking, trust, and responsible use in engineering education settings.

A total of 185 valid responses were included in analysis. Respondents represented multiple engineering majors and academic levels, with most students reporting moderate-to-high academic course loads (e.g., 3 or 4+ engineering courses). This sample size supports both descriptive reporting and basic inferential comparisons across student subgroups.

Survey Measures

AI Use Frequency

Students were asked: “How frequently do you use AI-based tools (e.g., ChatGPT, Copilot) for coursework?” with ordinal response options:

- Never (n = 10)
- Rarely (n = 49)
- Sometimes (n = 89)
- Often (n = 28)
- Very often (n = 9)

This item was treated as a categorical grouping variable for comparisons and as a predictor in regression-based modeling.

AI Attitudes (Likert Items)

Four attitude items were measured on a 5-point Likert scale:

1. AI improves understanding of course concepts.
2. Concern about critical thinking: overreliance on AI could weaken critical thinking.
3. Trust: AI provides accurate and ethical information.
4. Support responsible use of AI tools in coursework.

These four items are central to the paper’s claim of identifying the student climate toward AI adoption in engineering education.

Open-Ended Reflection

Students answered: “In what ways has the use of AI or technology changed how you learn or study?” This qualitative item provides contextual evidence and helps interpret quantitative results through student voice.

Composite Index Construction (AI Learning Attitudes Index)

To strengthen interpretation and allow inferential analysis beyond individual items, this study operationalizes an overall AI Learning Attitudes Composite Index. Because one item measures concern about negative impacts (“overreliance could weaken critical-thinking skills”), it was reverse-coded so that higher scores consistently reflect more favorable attitudes toward AI-supported learning and responsible implementation. Let:

- $Q13$= AI improves understanding
- $Q14$= worry overreliance weakens critical thinking
- $Q15$= trust AI accurate/ethical
- $Q16$= support responsible use

Reverse-coding was applied to $Q14$using:

$$Q14_{rev} = 6 - Q14$$

The composite index was then computed as the mean of the aligned items:

$$Composite = \frac{Q13 + Q14_{rev} + Q15 + Q16}{4}$$

This produces a composite score ranging from 1 to 5, where higher values indicate stronger pro-AI attitudes and support for responsible integration.

Statistical Analysis Plan

Analyses were conducted at three levels:

1. Descriptive analysis: frequency tables, means, and distributions of survey responses.
2. Scale reliability assessment: Cronbach's alpha for the composite index items to evaluate internal consistency.
3. Inferential analysis and advanced modeling:
   - One-way ANOVA comparing composite attitudes across AI use frequency groups.
   - Linear regression predicting composite attitudes using AI use frequency and academic factors (academic level, course load).

Qualitative responses were summarized using thematic grouping focused on common learning-related patterns (e.g., studying efficiency, explanation clarity, exam preparation, reliance concerns).

Results

Descriptive Findings for AI Learning and Attitudes Items

Students responded to four Likert-scale items measuring perceptions and attitudes toward AI tools in engineering education: (1) perceived learning benefit, (2) concern about overreliance weakening critical thinking, (3) trust in accuracy and ethical content, and (4) support for responsible AI use. Across the sample, students expressed moderate-to-positive views regarding the educational usefulness of AI, particularly related to learning support and the value of responsible integration. At the same time, responses reflected continued concern about overreliance and uncertainty regarding trust in AI outputs, suggesting that students' views are not uniformly optimistic and include both perceived benefits and perceived risks.

Figure 1 shows that Mechanical Engineering students made up the largest portion of the sample (39.0%), followed by Civil Engineering (22.2%) and Biomedical Engineering (18.7%). Smaller groups included Environmental Engineering (7.8%), Computer Engineering (5.6%), Electrical Engineering (3.3%), Industrial Engineering (2.2%), and Industrial Management (1.2%).

This distribution suggests that the study primarily reflects perspectives from traditional engineering disciplines, particularly Mechanical and Civil Engineering, while also capturing input from a diverse range of related fields.

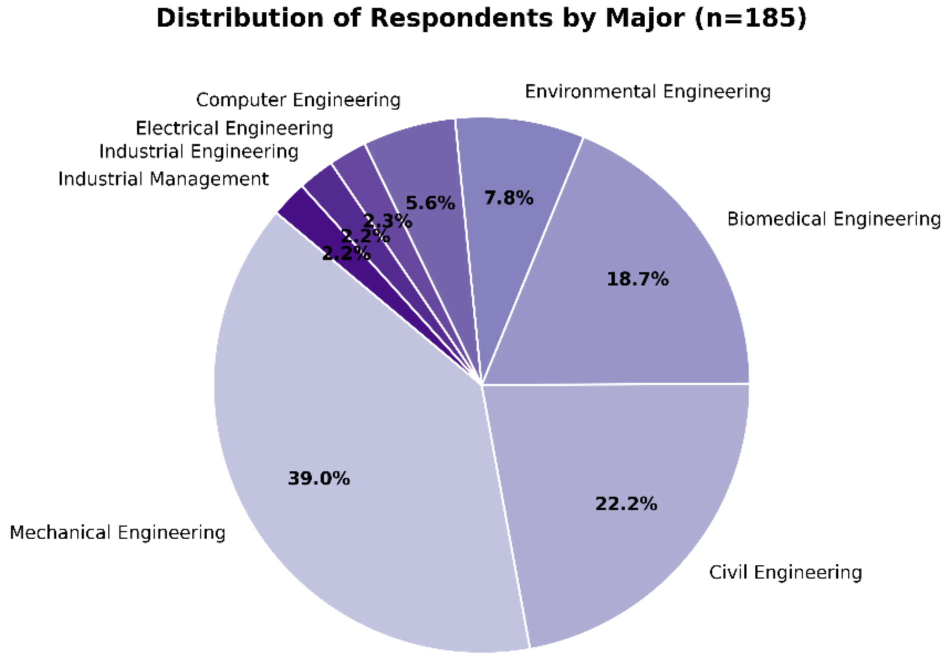

Figure 1: Distribution of Respondents by Engineering Major

Figure 2 indicates that the largest group of participants was freshmen (35.7%), followed by sophomores (26.5%), juniors (18.4%), and seniors (17.8%), while only 1.6% of respondents were graduate students. This distribution suggests that the survey primarily captured the perspectives of lower-division undergraduate students, reflecting their early-stage engagement with artificial intelligence tools within engineering programs.

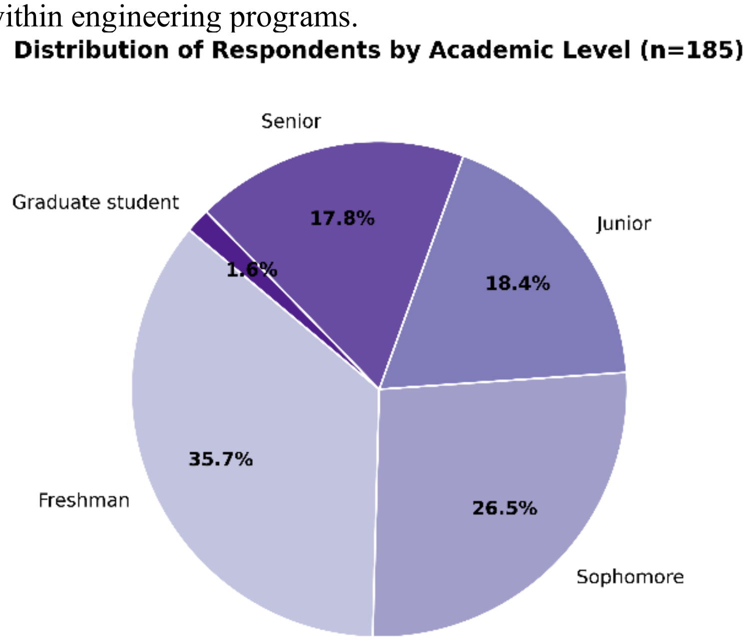

Figure 2: Distribution of respondents by academic level

Figure 3 shows that nearly half of the respondents (46.5%) reported taking four or more engineering courses, followed by 20.5% taking two courses, 16.8% taking one course, and 16.2% taking three courses. This distribution suggests that the majority of surveyed students had a relatively high academic load, which may influence how frequently they rely on AI-based tools to manage coursework and study tasks.

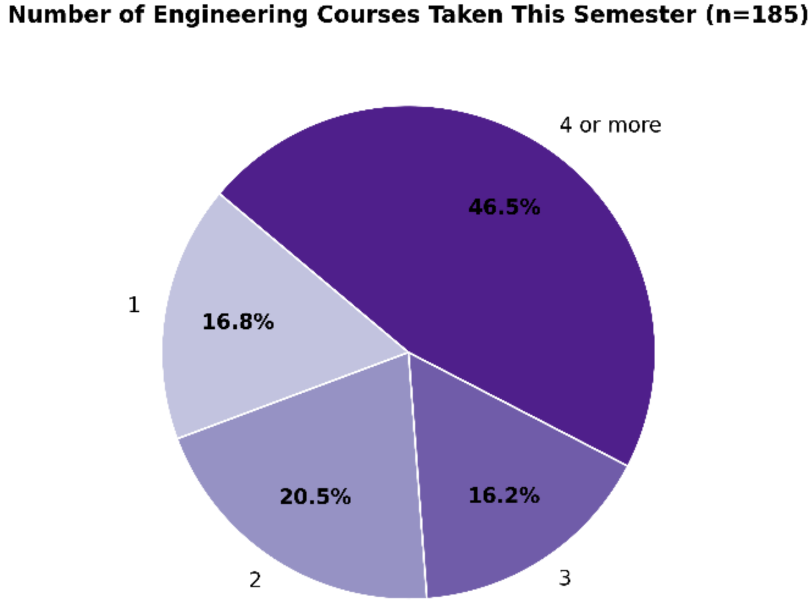

Figure 3. Number of engineering courses taken this semester

AI Tools in Learning

Nearly half of the students (48.1%) reported using AI-based tools "sometimes", while 26.5% indicated using them "rarely." A smaller portion used AI "often" (15.1%) or "very often" (5.3%), and only 5.0% reported never using such tools (Figure 4). These results suggest that while AI-based tools have become a regular part of student learning, their usage remains primarily moderate, with most students employing them occasionally rather than as a dominant academic aid.

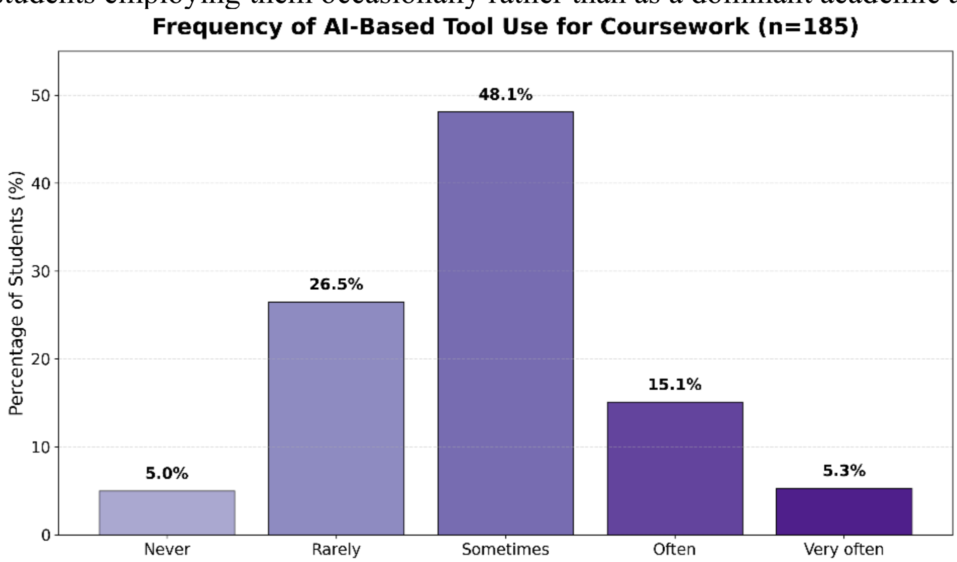

Figure 4: Frequency of AI-based tool use for coursework

The majority of students reported using AI tools for homework help (76.8%) and exam preparation (61.6%), followed by idea generation (43.2%). A smaller percentage used AI for report writing (15.7%) and coding/debugging (15.1%) according to Figure 5. These findings indicate that students primarily employ AI tools for academic support tasks that enhance understanding and productivity rather than for advanced technical functions such as coding or automated report generation.

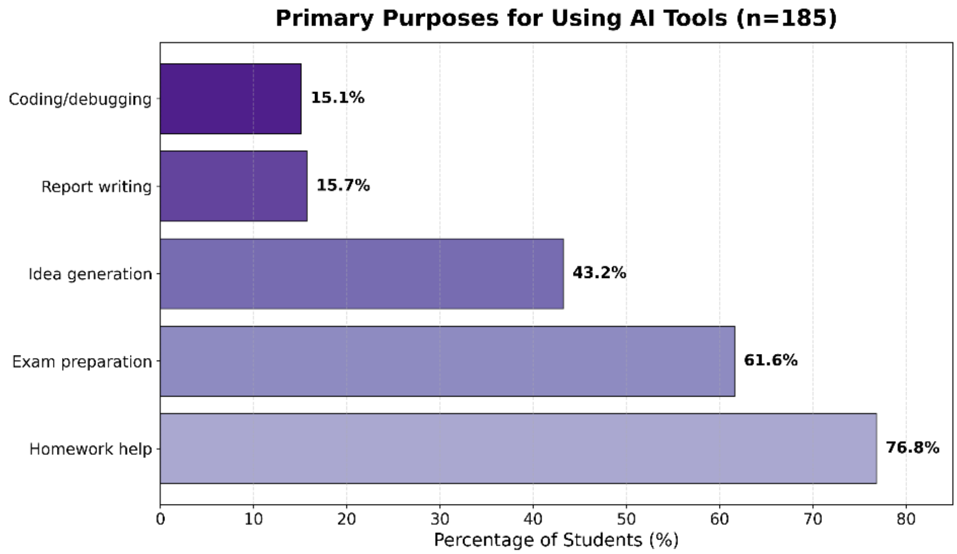

Figure 5: Primary purposes for using AI tools

Figure 6 shows that most respondents agreed that AI tools enhance their understanding of course materials, with 36.8% selecting "4" and 26.5% selecting "5" on a 5-point scale. Meanwhile, 25.9% were neutral ("3"), and only 10.8% expressed disagreement ("1" or "2"). These findings indicate a generally positive perception of AI's educational value, suggesting that students view AI tools as effective supplementary resources for improving comprehension and conceptual learning.

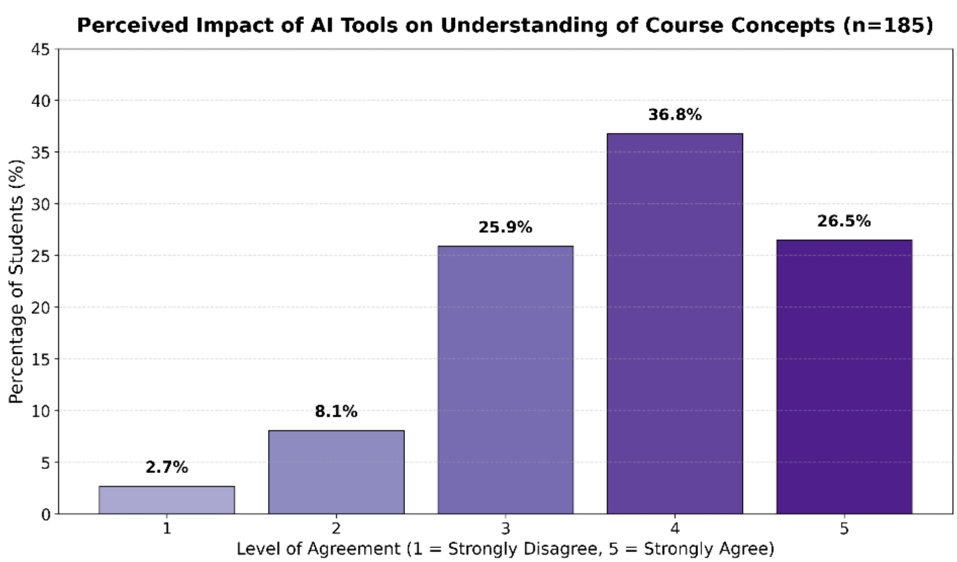

Figure 6: Perceived impact of AI tools on understanding of course concepts

Responses show that over half of the students (49.7%) agreed or strongly agreed (ratings 4-5) that excessive dependence on AI might reduce their ability to think critically. About 27.0% expressed neutrality ("3"), while only 23.3% disagreed or strongly disagreed (ratings 1-2). These results suggest that although students generally value AI's benefits, many remain mindful of its possible drawbacks, recognizing the need for balance between leveraging AI assistance and maintaining independent problem-solving skills (Figure 7).

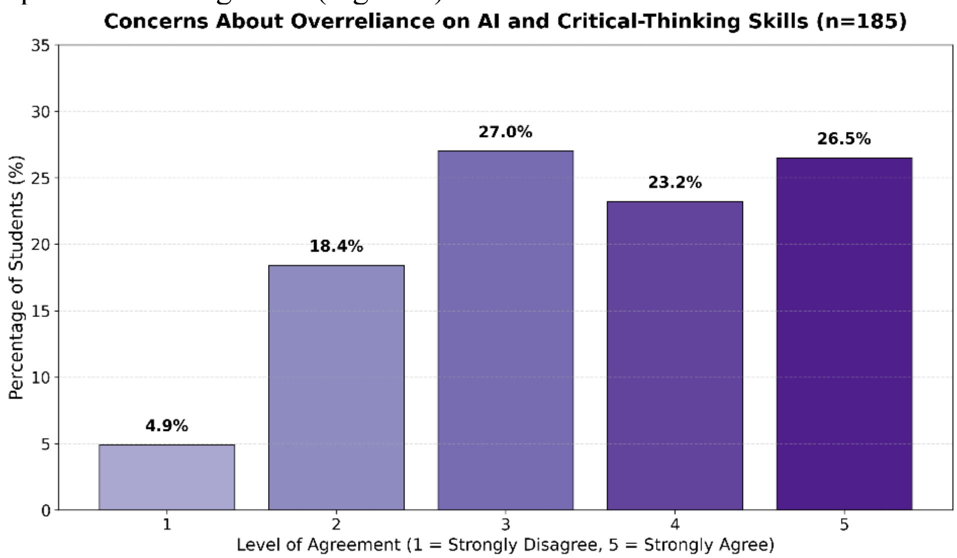

Figure 7: Concerns about overreliance on AI and its potential impact on critical-thinking skills

Figure 8 shows that most students reported moderate or low trust levels, with 41.1% selecting "3" (neutral) and 31.4% choosing "2." Only 15.1% expressed higher trust (ratings 4-5), while 12.4% strongly disagreed with the statement. These findings reveal that while students are open to using AI in coursework, they remain cautious about its reliability and ethical integrity, suggesting that educational strategies should emphasize critical evaluation of AI-generated content.

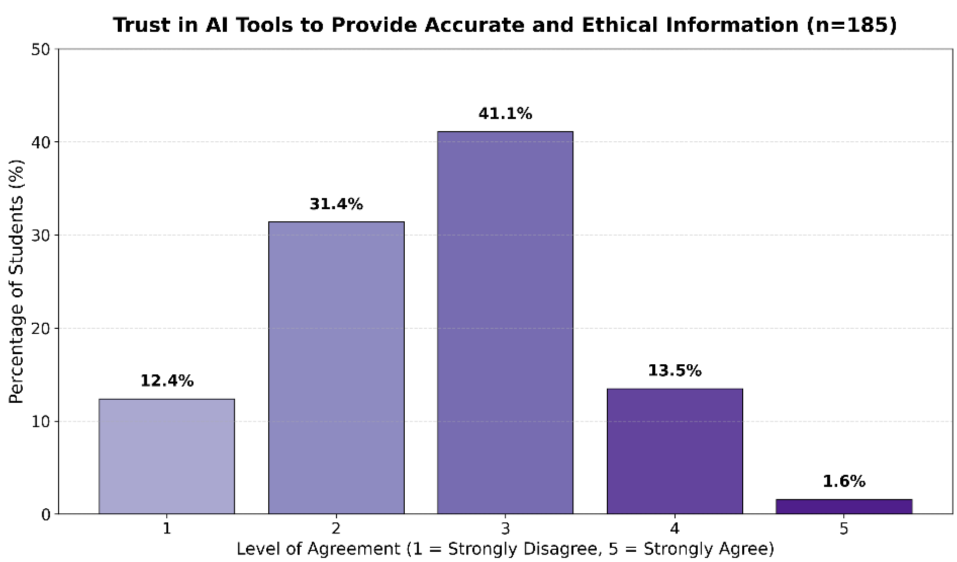

Figure 8: Trust in AI tools to provide accurate and ethical information

Most students expressed strong support for integrating AI tools responsibly in academic settings, with 40.5% selecting “4” and 28.6% selecting “5.” Meanwhile, 21.6% remained neutral, and only 9.1% disagreed (ratings 1-2) as shown in Figure 9. These results highlight broad endorsement among students for using AI in education when guided by ethical and responsible practices. This reflects growing awareness of both the benefits and the need for appropriate boundaries in AI-assisted learning.

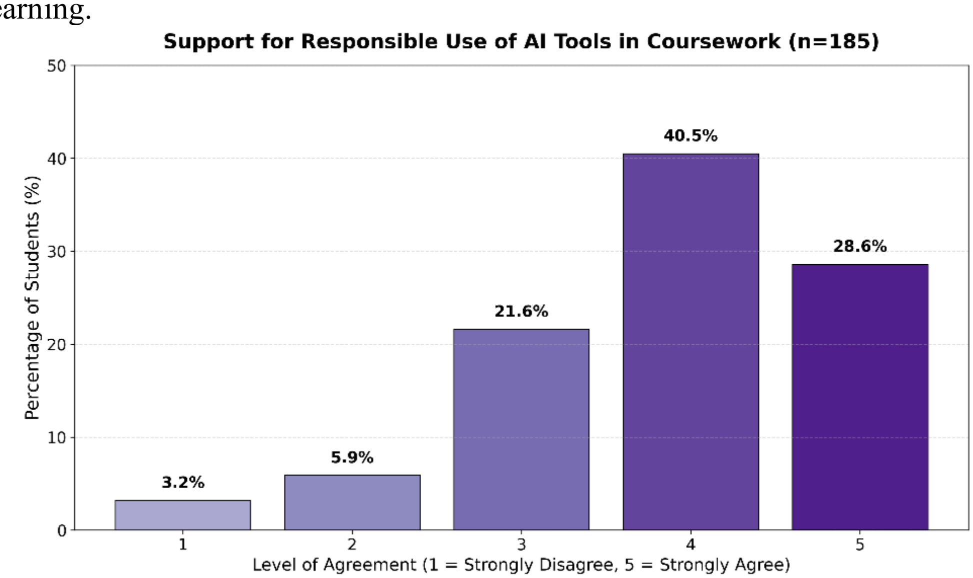

Figure 9: Support for responsible use of AI tools in coursework

Composite AI Learning Attitudes Index

To provide an overall summary measure of student attitudes toward AI-supported learning, the four Likert items were combined into a Composite AI Learning Attitudes Index. Prior to index construction, the critical-thinking concern item was reverse-coded so that all items aligned directionally (higher values indicate more positive attitudes toward AI as a learning support tool and stronger endorsement of responsible implementation). The composite index was calculated as the mean of the four aligned items. The composite index showed moderate overall agreement across respondents:

- Mean = 3.19
- Standard deviation = 0.74
- Minimum = 1.00, maximum = 4.75
- Median = 3.25

These descriptive statistics indicate that, on average, students were more supportive than neutral, while also demonstrating meaningful variability across respondents.

Reliability of the Composite Index

Internal consistency reliability of the composite index was assessed using Cronbach’s alpha. The results showed moderate reliability ($\alpha = 0.67$). Given the small number of items and the fact that they reflect multiple related dimensions of AI perceptions (benefit, trust, risk awareness, and responsible use), this value is considered acceptable for exploratory, survey-based educational research and supports the use of both composite and item-level reporting.

Differences in Composite Attitudes by AI Use Frequency

Substantial differences were observed in composite index scores across student groups based on AI use frequency. Mean composite scores increased consistently as AI use frequency increased:

- Never: 1.88
- Rarely: 2.88
- Sometimes: 3.31
- Often: 3.52
- Very Often: 4.00

This pattern suggests a strong association between students' engagement with AI tools and their overall attitudes toward AI-assisted learning. A one-way ANOVA confirmed that differences in composite index values across use-frequency groups were statistically significant. The results are shown in Table 2.

Table 2 One-way ANOVA Results (Composite Index by AI Use Frequency)

Source	SS	df	MS	F	p
AI use frequency	32.151	4	8.038	20.95	< 0.001
Residual	69.070	180	0.384	—	—
Total	101.221	184	—	—	—

Regression Modeling of AI Learning Attitudes (Advanced Analysis)

To further examine whether differences in AI learning attitudes persist after accounting for academic characteristics, a multiple linear regression model was estimated with the Composite AI Learning Attitudes Index as the dependent variable. The model included AI tool use frequency, academic level, and engineering course load as predictors. AI use frequency was entered as a categorical variable using "Never" as the reference group. Results indicated that AI use frequency was a statistically significant predictor of composite attitudes. Specifically, compared to students who reported never using AI tools, students reporting use Sometimes ($B = 1.39$, $p < 0.001$), Often ($B = 1.61$, $p < 0.001$), and Very Often ($B = 1.93$, $p < 0.001$) had significantly higher composite index scores. The coefficient plot (Figure 2) further demonstrates that the effect of AI frequency was consistently positive across higher-frequency groups, with confidence intervals not crossing zero. In contrast, academic level predictors were not statistically significant once AI use frequency was included in the model, suggesting that students' attitudes toward AI-assisted learning are primarily associated with the degree of engagement with AI tools rather than academic seniority. The results are shown in Table 3.

Table 3 Linear Regression Predicting Composite AI Learning Attitudes Index

Predictor	B	SE	t	p
Intercept	1.998	0.525	3.81	<0.001
Rarely (vs Never)	0.648	0.332	1.95	0.054
Sometimes (vs Never)	1.392	0.316	4.41	<0.001
Often (vs Never)	1.611	0.339	4.76	<0.001

Very Often (vs Never)	1.934	0.425	4.55	<0.001
Graduate student	-0.140	0.731	-0.19	0.848
Junior	-0.179	0.436	-0.41	0.682
Senior	0.215	0.445	0.48	0.630
Sophomore	-0.087	0.437	-0.20	0.842

Qualitative Results from Open-Ended Responses

Analysis of the open-ended responses revealed several key themes regarding how AI has influenced students' learning and study habits. Many students reported that AI tools enhance their understanding by clarifying complex concepts, explaining topics in multiple ways, and breaking down complex problems into manageable steps. Others highlighted the value of AI in generating practice materials, such as custom quizzes, study guides, and mock exam questions to reinforce learning and improve exam preparedness. An everyday use was for homework and problem-solving support, with students relying on AI to verify answers, identify mistakes, and receive step-by-step guidance when instructor assistance was unavailable. Several participants noted that AI improved their study efficiency and organization by streamlining project management, summarizing readings, and condensing information; however, some cautioned that a heavy reliance on AI could reduce critical thinking. Additional mentions included using AI for programming assistance, grammar correction, and quick information summaries. Notably, a small portion of respondents (approximately 15) indicated that they rarely or never use AI tools in their academic work.

Discussion

This study examined undergraduate engineering students' engagement with AI-based tools (e.g., ChatGPT, Copilot) and their perceptions of how these tools influence learning, critical thinking, trust, and responsible use. Findings demonstrate that AI tools are not a peripheral technology in engineering education; rather, they are already embedded in students' academic routines. Most students reported using AI tools at least occasionally, with "sometimes" being the most common usage frequency. Students also reported using AI primarily for coursework support activities such as homework help, exam preparation, and idea generation. These patterns reinforce the notion that generative AI is being adopted as a practical learning aid rather than as a specialized tool used only in advanced computing tasks or writing-heavy assignments.

These findings are consistent with and extend prior research documented in the literature review. The widespread adoption of AI tools for homework help and exam preparation aligns with Yeung et al. [8], who found that university students in Hong Kong recognized GenAI as highly useful for learning support, information gathering, and summarizing academic content. Similarly, Bernabei et al. [9] reported that engineering students perceived ChatGPT as reliable for accelerating task completion and enhancing performance, a perception echoed in the present study's finding that most students believe AI improves their understanding of course concepts. The current study extends these findings to a U.S. based engineering student population across multiple majors and academic levels, suggesting that the positive perception of AI as a learning aid is not isolated to specific institutional or cultural contexts but may reflect a broader phenomenon in STEM higher education.

A key finding is that students generally perceive AI as beneficial to learning, particularly in helping them better understand course concepts. A large proportion of respondents agreed that AI tools improve comprehension, which aligns with prior research identifying GenAI as a resource that can provide step-by-step explanations, clarify difficult topics, and function as an on-demand tutor-like support system. This perceived benefit is particularly relevant for engineering curricula, where students often encounter abstract concepts and complex multi-step problem-solving. In these contexts, AI can provide immediate clarification and reduce learning friction, especially outside office hours.

However, these benefits should be interpreted cautiously. Students may perceive AI as improving understanding because it accelerates access to explanations, examples, and solutions, but perceived understanding does not always equate to deep conceptual mastery. Engineering learning outcomes depend not only on correctness, but on the reasoning process, troubleshooting, and the ability to justify decisions. Therefore, the educational value of AI depends heavily on how students use it (e.g., explanation-based use vs. answer-generation use).

The dataset reveals a meaningful tension: while students recognize AI as helpful, many also acknowledge the risk that overreliance could weaken critical-thinking skills. This "critical thinking paradox" represents one of the most important implications for engineering education. Students appear to be aware that AI can reduce effortful thinking, even as they continue to use it for efficiency and support. This finding suggests that AI use is not solely driven by academic dishonesty or avoidance of work; rather, it may reflect rational adaptation to workload, time constraints, and the pressure to perform in high-demand engineering courses.

This tension between perceived benefit and concern about cognitive dependency is consistent with themes running across multiple studies in the literature review. Schmidt et al. [10] and Prilop et al. [11] both found that educators, despite valuing AI's transformative potential, expressed concern that overreliance could diminish students' critical thinking and independent problem-solving abilities. Notably, the present study shows that students themselves share this concern, suggesting that awareness of the "critical thinking risk" is not confined to faculty but is already internalized by learners. This represents a meaningful advance beyond prior work: where earlier studies primarily captured educator perspectives on this tension [10], [11], [13], the current data confirm that the concern is present and statistically measurable at the student level. The findings of Tian and Zheng [28], who found through meta-analysis that AI can support students' higher-order "4C skills" (creativity, critical thinking, communication, and collaboration), offer a constructive counterpoint: with intentional design, AI need not erode critical thinking but can instead scaffold its development. The present study's results support this possibility, given that students simultaneously express concern about overreliance and strong support for responsible use—indicating readiness for structured AI integration.

From an instructional standpoint, this dual perception provides an opportunity. Students are already aware of the risk of cognitive dependency, meaning faculty can build on this awareness by explicitly teaching structured, responsible AI workflows. For example, instructors can require students to show intermediate steps, justify assumptions, and compare AI-generated outputs with manual reasoning. Rather than treating AI as inherently harmful, results support a framework where AI is treated as a tool that must be paired with verification and reflection.

While students frequently use AI tools, trust remains notably limited. Most respondents selected low or neutral trust levels regarding whether AI provides accurate and ethical information. This skepticism is consistent with widely recognized limitations of generative AI systems such as hallucination, inconsistency, and opacity (black-box behavior). These results indicate that students may already intuitively recognize that AI outputs require verification. This finding has strong implications for engineering pedagogy. Engineering disciplines often operate under safety, reliability, and ethical accountability requirements. If students use tools they do not fully trust, it raises concerns about the integration of unverified content into learning and assessment processes. This strengthens the argument that engineering education should include explicit training in AI verification practices, including cross-checking with textbooks, lecture notes, validated datasets, and domain standards.

The low trust levels observed in this study align closely with findings reported throughout the literature on AI limitations. Safitra et al. [20] and Einarsson et al. [20a] warned that AI systems can generate incorrect, biased, or incomplete information, a concern that appears to have filtered into students' intuitive skepticism about AI accuracy. De Moura Oliveira and Vrančić [21] and Németh et al. [22] similarly highlighted hallucination as a critical limitation of current LLM-based tools, noting that outputs cannot yet be fully trusted without human verification. Vega-Rebolledo et al. [26] further pointed to the "black box" opacity of AI systems as a source of public distrust. The present study's finding that most engineering students do not trust AI to provide accurate and ethical information resonates with Lyu et al. [25], who found that a majority of instructors prohibit GenAI use precisely due to concerns about academic integrity and uncertain reliability. Taken together, these results suggest that low trust is not merely a knowledge gap that can be resolved through better marketing of AI tools; rather, it reflects a rational response to documented limitations that engineering education programs must address directly through AI literacy training and verification skill-building.

Despite concerns about critical thinking and trust, students strongly supported the responsible use of AI tools in coursework. This is one of the most actionable findings in the study. The strong endorsement indicates students are open to structured guidance and boundaries rather than unrestricted or hidden use. This implies that engineering programs may be able to implement clear, consistent AI policies with a focus on learning outcomes rather than simple prohibition. Additionally, the presence of both high adoption and demand for responsible use suggests that future instruction should emphasize transparency and norms. For example, universities can introduce policies for disclosure of AI use, define acceptable and unacceptable applications, and integrate "AI ethics modules" into foundational engineering courses.

The strong student support for responsible AI use observed here complements and extends prior research on institutional AI policy. Bittle and El-Gayar [7] conducted a systematic review of GenAI and academic integrity, concluding that institutions need robust frameworks that promote ethical use rather than blanket prohibition, a conclusion this study's data support from the student perspective. Zhuang et al. [16] similarly emphasized the importance of fairness, accountability, and transparency in AI-assisted instruction. The present finding that students actively endorse responsible use represents a significant contribution to this literature: rather than positioning students as reluctant adopters who must be constrained by policy, the data suggest students are willing partners in responsible AI governance. This finding also aligns with Oliveira et al. [27], who argued that students must leverage their domain-specific knowledge to guide AI toward reliable outputs, and with Avci et al. [12], who found that STEM educators recognize AI as a cognitive aid that should complement rather than replace disciplinary reasoning. The implication for AI literacy in engineering education is clear: programs should move beyond policing AI use and instead invest in developing students' capacity to engage with AI tools critically, responsibly, and in ways that reinforce rather than undermine their engineering judgment.

The most statistically robust finding of this study is the relationship between AI use frequency and the Composite AI Learning Attitudes Index. Both ANOVA and regression analyses showed that students who used AI more frequently reported significantly higher composite scores. This was true even after controlling for academic level and course load, indicating that attitudes were primarily associated with engagement rather than seniority. This gradient supports the interpretation that experience with AI tools is linked to more favorable views. It may reflect that frequent users perceive more benefits, gain confidence in using these tools, and integrate them into their learning process. Conversely, non-users or rare users may lack exposure, perceive higher risk, or maintain greater skepticism. While the data are not longitudinal and cannot establish causality, the patterns strongly suggest that usage frequency is a key factor shaping perception and acceptance.

The relationship between AI use frequency and attitudes situates this study within the broader scholarly conversation on AI literacy and adoption. Lyu et al. [25] found that instructors who used GenAI themselves held more nuanced views about its appropriate application, a parallel dynamic to what this study observes at the student level. The frequency-attitude gradient also resonates with the technology adoption research referenced in Schmidt et al. [10], where both students and faculty who engaged more directly with AI tools developed more informed and differentiated views of both benefits and risks. Importantly, this study goes beyond simply documenting the correlation: by including academic level and course load as control variables and finding that these factors do not explain attitude differences, the analysis isolates engagement as the primary driver. This suggests that AI literacy interventions should be experiential rather than informational, students may develop more calibrated, responsible attitudes toward AI not primarily through lectures about AI policy, but through guided, hands-on use of these tools in authentic engineering learning contexts. This insight aligns with the implementation strategies highlighted by Tian and Zheng [28] and Wang et al. [29], who emphasized AI's role as an active tutor and assistant in developing students' higher-order competencies when used in structured, purposeful ways.

Taken together, these findings provide a foundation for AI-assisted learning analytics aimed at personalized STEM instruction. Because students vary meaningfully in use frequency, trust, and attitudes, one-size-fits-all policies are unlikely to be effective. Instead, learning analytics frameworks can be designed to identify student patterns and tailor interventions accordingly—for example, supporting low-use students with AI literacy training, while guiding high-use students toward verification practices and critical thinking reinforcement. Finally, the qualitative responses strengthen the quantitative findings by showing that students commonly use AI for concept clarification, study efficiency, and problem-solving support. These insights reinforce the need for educational strategies that harness AI for scaffolding and comprehension while preventing harmful dependence or displacement of reasoning.

Summary and Conclusion

This study investigated how undergraduate engineering students use AI-based tools for coursework and how they perceive AI's influence on learning. Using survey data from 185 students, the analysis examined AI tool usage frequency, primary uses of AI, and student attitudes across four dimensions: learning benefit, critical thinking concerns, trust in AI outputs, and support for responsible use. To strengthen analysis, a Composite AI Learning Attitudes Index was developed and tested with reliability assessment, ANOVA, and regression modeling. Descriptive results show that AI adoption is widespread, with most students reporting at least occasional use. AI tools were most commonly used for homework assistance and exam preparation, indicating that students primarily use AI as a study and learning aid. Students generally agreed that AI supports understanding of course concepts, but many also expressed concern that overreliance may weaken critical-thinking skills. Trust in AI accuracy and ethical reliability was relatively low, yet students strongly supported responsible integration of AI tools in coursework.

Inferential results indicated significant differences in composite attitudes across AI use frequency groups. Students who used AI tools more frequently reported significantly stronger overall AI learning attitudes. Regression modeling showed that AI use frequency remained a dominant predictor of composite attitudes after controlling for academic level and engineering course load, suggesting that engagement with AI tools is the primary factor associated with student perceptions.

The results indicate that generative AI tools are already integrated into engineering students' academic routines, shaping how they study, prepare for exams, and approach homework. Students view AI as beneficial for learning, but simultaneously recognize its risks—particularly the potential for reduced critical thinking if used excessively. While students do not consistently trust AI tools to provide accurate and ethical information, they nonetheless support responsible use, revealing openness to structured educational guidance and policy development. These findings suggest that engineering education should move toward intentional integration rather than reactive restriction. Instructional strategies should prioritize AI literacy, critical evaluation of outputs, and responsible-use norms, ensuring that AI functions as an educational scaffold rather than a substitute for engineering reasoning. Future research should examine longitudinal effects, explore causal relationships between AI use and attitudes, and connect AI usage patterns to objective learning outcomes such as performance, conceptual mastery, and the development of engineering problem-solving skills.

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