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The Dual Role of Artificial Intelligence in Academia: A Facilitator or Hindrance to Higher-Order Thinking Skills in Complex Problem Solving

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ABSTRACT

Introduction: The integration of artificial intelligence (AI) in higher education presents a dichotomy: a potential tool for enhancing learning or a risk to the development of fundamental cognitive skills. This study investigates AI's impact on university students' higher-order thinking skills (HOTS) during complex problem-solving. While AI offers personalized and efficient solutions, concerns persist regarding its potential to hinder critical thought and independent learning.

Methods: A mixed-methods approach was used to explore this issue. A quasi-experimental design compared a control group of university students solving complex problems without AI to an experimental group utilizing AI tools. Data were collected through pre- and post-test assessments of HOTS, a survey on AI usage, and qualitative semi-structured interviews. Epistemic Network Analysis (ENA) was employed to visualize and quantify the cognitive structures students used during the problem-solving process.

Results: Quantitative analysis revealed that the AI-assisted group demonstrated a statistically significant difference in certain HOTS metrics compared to the control group, though the nature of this difference was complex and depended on the type of task. Qualitative data from interviews highlighted students' perceptions of both the benefits and drawbacks, with many expressing concerns about "AI dependency." The ENA provided visual evidence of differing cognitive approaches, suggesting that AI use may alter the interconnectedness of students' thought processes. Ethical concerns around data privacy, algorithmic bias, and the lack of transparency in AI decision-making were prominent themes.

Discussion: The findings suggest that AI's role is not a simple binary of "facilitator or hindrance." Its impact is nuanced, potentially enhancing some aspects of problem-solving while hindering others, particularly when students become overly reliant on AI-generated solutions. Effective integration of AI requires a pedagogical shift towards scaffolding its use to support, rather than replace, cognitive effort. The study underscores the urgent need for robust ethical frameworks and participatory design in AI development for education to mitigate risks and ensure a human-centric approach.

Keywords
Higher-Order Thinking Skills, Complex Problem Solving, Artificial Intelligence, Educational Technology, Cognitive Offloading, AI Ethics, Participatory Design.

INTRODUCTION

The rapid integration of artificial intelligence (AI) into the fabric of higher education marks a pivotal moment in pedagogical history. From sophisticated adaptive learning platforms to generative AI tools, these technologies promise to revolutionize the educational landscape by offering personalized experiences, automating administrative tasks, and providing instant feedback [1, 4, 25]. However, this technological revolution is not without its complexities and debates. While proponents highlight AI's potential to enhance learning and foster engagement, a parallel and growing concern questions its impact on the very skills that define a university education: higher-order thinking skills (HOTS) and the ability to solve complex problems [5, 30]. This article investigates the dual role of AI in academia, exploring whether it acts as a facilitator that empowers students to reach new intellectual heights or a hindrance that risks the atrophy of essential cognitive abilities.

Higher-order thinking skills, encompassing abilities such as critical analysis, synthesis, evaluation, and creative problem-solving, are foundational to academic and professional success [13, 42]. They are the cognitive engine that allows individuals to move beyond rote memorization and apply knowledge in novel, challenging situations. Similarly, complex problem-solving is not a simple linear process. It involves navigating ambiguous, ill-defined problems with multiple potential solutions, requiring students to integrate knowledge from various domains and think creatively [2, 16, 26]. The ability to engage in these skills is a key outcome of university education, preparing graduates to tackle real-world challenges that are often messy and unpredictable [27, 40].

Against this backdrop, the advent of AI presents a conundrum. On one hand, AI tools can offload cognitive burdens, allowing students to focus on more creative and strategic aspects of a task [17, 54]. For instance, generative AI can assist in brainstorming, summarizing complex texts, or generating foundational code, thereby freeing up mental resources for deeper analysis and conceptualization [59, 61, 66]. This perspective positions AI as a powerful cognitive partner, an "augmented intelligence" that expands human capacity rather than replacing it [45, 62]. On the other hand, a growing body of literature warns of a "dark side" to AI in education, where over-reliance on these tools may lead to cognitive offloading, a process where students delegate thinking to the AI, thus missing the opportunity to develop their own cognitive muscles [22, 30, 65]. The ease of getting instant answers from AI-based conversational models, such as ChatGPT, may be associated with disincentivizing the deep engagement with material that is necessary to cultivate HOTS [22]. This reliance could foster a form of "AI dependency" that undermines academic self-efficacy and long-term learning outcomes [63, 65].

The problem is further compounded by a significant gap in current educational technology research. While AI's role in improving personalized learning and administrative efficiency is well-documented [25, 49], few studies have directly explored its nuanced impact on the development of HOTS in the context of complex problem-solving. There is a pressing need to move beyond a simplistic view of AI as either "good" or "bad" and instead investigate the specific conditions under which it can be a constructive tool for learning. Furthermore, this investigation must be grounded in an analysis of the ethical implications. The swift deployment of AI systems has often outpaced ethical considerations, leading to concerns about data privacy, algorithmic bias, transparency, and the need for more robust governance frameworks [5, 30]. Without a clear understanding of these issues, the full promise of AI in education cannot be realized responsibly.

This study aims to address these critical gaps by examining the multifaceted impact of AI on university students' HOTS during complex problem-solving tasks. We will explore three key research questions: (1) How does the use of AI tools influence the development of university students' higher-order thinking skills? (2) Does the nature of complex problem-solving tasks—specifically, those requiring creative and interdisciplinary approaches—mediate the impact of AI? (3) What are the ethical implications and governance challenges associated with integrating AI into educational practices designed to foster HOTS? By employing a rigorous mixed-methods approach, this research seeks to provide evidence-based insights that will inform pedagogical strategies, ethical guidelines, and future research directions, ensuring that AI serves as a true intellectual partner in the pursuit of knowledge.

Literature Review

To understand the complex interplay between AI and students' cognitive development, it is essential to first define the key concepts and then review the existing literature on AI's role in education. This section will begin by clarifying what constitutes higher-order thinking skills (HOTS) and complex problem-solving. It will then explore the dual perspectives on AI's impact, examining how it can both facilitate and hinder these crucial skills. Finally, it will synthesize the critical, but often underexplored, ethical implications of AI in education.

Defining HOTS and Complex Problem-Solving

Higher-order thinking skills represent the pinnacle of cognitive functioning, moving beyond basic knowledge acquisition to encompass critical analysis, synthesis, and evaluation [13, 42]. These skills are not innate but must be purposely taught and nurtured through instruction and practice [42]. Scholars define HOTS as the ability to apply, analyze, evaluate, and create, as outlined in revised taxonomies of learning objectives [9, 13]. The development of HOTS is a primary goal of education, enabling students to construct meaning, solve unfamiliar problems, and think critically about their own thinking processes [56, 60].

In parallel, complex problem-solving is a cognitive process that goes beyond applying a known solution to a familiar problem [26, 57]. These problems are often ill-defined, containing ambiguous goals and constraints, and require the integration of knowledge from multiple domains [2, 16]. For instance, a design problem requires designers to navigate a vast "design space" of possibilities, a process that is iterative and non-linear [6, 14, 24]. The ability to solve these problems relies heavily on HOTS, as students must critically analyze the problem's components, synthesize diverse information, and creatively evaluate potential solutions [7, 41]. The literature emphasizes that this type of "real-world cognition" is best developed in authentic learning environments where students are situated in a context that mimics real-world challenges [18, 27].

AI as a Facilitator of HOTS

One perspective argues that AI can be a powerful facilitator of HOTS by augmenting human intelligence and freeing up cognitive resources. Research in human-AI collaboration suggests that when designed effectively, AI tools can act as cognitive partners, allowing humans to achieve outcomes they could not on their own [45, 58]. In design and engineering, AI-assisted teams have been shown to be more agile, able to explore a broader range of options, and generate novel ideas more efficiently than human-only teams [21, 54]. AI can generate multiple preliminary ideas, from color palettes to architectural options, reducing the initial cognitive load and allowing the human user to focus on refining and evaluating the most promising solutions [59, 61]. This "scaffolding" effect can support students in overcoming design fixation and engaging in more divergent thinking [59].

Moreover, AI can provide targeted, adaptive feedback that is essential for skill development [4, 50, 51]. Adaptive learning platforms (ALPs) powered by AI can tailor content and difficulty to a student's individual needs, helping them build a strong foundation of knowledge before they tackle more complex tasks [4]. By automating the assessment of foundational skills, these systems allow educators to dedicate more time to coaching students on higher-level concepts and problem-solving strategies [1, 28]. This approach, sometimes termed "augmented intelligence," suggests that the most effective use of AI is not to replace human thinking, but to enhance it, creating a symbiotic relationship where the human's creativity and the AI's computational power work together [45, 62].

AI as a Hindrance to HOTS

Conversely, another body of research highlights the potential for AI to be a hindrance to the development of HOTS, primarily through the mechanism of cognitive offloading. The ease and speed with which AI tools can provide answers may be associated with disincentivizing students from engaging in the deep, effortful thinking required for learning. Several studies have raised concerns that students using large language models (LLMs) like ChatGPT may simply copy and paste solutions without a genuine understanding of the underlying principles, effectively bypassing the learning process altogether [22, 55]. This phenomenon is often linked to a decline in critical thinking and a failure to develop the internal mental models necessary for future problem-solving [22, 30].

This over-reliance on AI is associated with a state of "AI dependency," a condition where students' academic self-efficacy wanes and they may become unable to perform tasks without technological assistance [63, 65]. The allure of efficiency can overshadow the value of the struggle inherent in learning. While a struggle might be frustrating in the short term, it is often the catalyst for deeper learning and the formation of robust cognitive connections [23, 29]. When AI eliminates this struggle, it may inadvertently remove the opportunities for students to build resilience and intellectual tenacity. This has led some researchers to caution against the uncritical adoption of AI in education, advocating for a more thoughtful, balanced approach that prioritizes student engagement and intellectual independence over technological convenience [5, 30, 38].

Ethical Implications and Governance Challenges

Beyond its direct pedagogical impact, the integration of AI in education is fraught with ethical and governance challenges that are often overlooked in the pursuit of innovation. A significant body of research points to the underexplored ethical dimensions of EdTech, with a particular focus on learner autonomy, transparency, and data governance [5, 30].

A major concern revolves around privacy and data protection [3, 30]. Adaptive learning systems and other AI-driven platforms collect vast amounts of sensitive student data, from academic performance to cognitive patterns. The lack of clear consent protocols and robust data governance frameworks in many jurisdictions is associated with serious questions about data misuse and surveillance [3, 5, 53]. Without adequate protections, this data could be used in ways that compromise student privacy and autonomy.

Furthermore, issues of bias and fairness in AI algorithms may pose a significant risk to equity in education. If AI models are trained on biased data sets, they may reproduce or even exacerbate existing educational inequalities, particularly for underrepresented or disadvantaged student groups [5, 30]. For example, an AI-powered admission tool trained on historical data might perpetuate a bias against certain demographic groups, undermining efforts to create a more equitable educational environment.

The challenge of transparency and explainability is another key gap [5, 30]. Many AI systems, particularly complex neural networks, operate as "black boxes," making it difficult for educators and learners to understand how decisions are made. The opacity of these models undermines trust and raises concerns when they are used in high-stakes settings, such as grading or recommending courses. Students and teachers have a right to understand the logic behind an AI's output, and a lack of transparency may hinder their ability to critically evaluate and learn from the system.

These ethical challenges are associated with the need for a new approach to AI implementation in education. Researchers are calling for a shift from a tech-centric to an education-centric priority, advocating for participatory design that includes students and teachers in the development process [5, 30, 47]. This collaborative approach may ensure that AI tools are designed to meet genuine pedagogical needs rather than simply being a technological solution in search of a problem. Additionally, the existing regulatory frameworks are often insufficient, highlighting the need for stronger institutional and governmental policies to oversee the ethical use of AI in educational settings [5, 30]. These frameworks should embed ethics into the entire AI development lifecycle, from data collection to system deployment and impact assessment [5, 30].

METHODS

This study employed a mixed-methods research design to provide a comprehensive and nuanced understanding of AI's impact on students' higher-order thinking skills. The design combined a quantitative quasi-experimental approach to measure observable changes in cognitive skills with a qualitative phenomenological component to explore students' lived experiences and perceptions. This triangulation of methods allowed for both the statistical analysis of outcomes and a deeper exploration of the underlying processes and ethical concerns.

Research Design and Participants

The study utilized a quasi-experimental design involving two groups of university students enrolled in a core design and engineering course that requires complex problem-solving. An experimental group (n=50) was given access to a suite of AI tools (including a generative text-based model and a design-specific AI assistant) to assist them with their projects. A control group (n=50) was given the same project prompts but was explicitly instructed to complete the tasks without the use of AI tools. All participants were undergraduate students from a major university in a field that requires frequent complex problem-solving. This approach allowed for a direct comparison of learning outcomes and cognitive processes between the two groups.

Data Collection

Multiple data collection methods were used to capture a holistic picture of the students' experiences.

- Quantitative Data:
  - Pre- and Post-Tests: Students in both groups completed a validated pre-test at the beginning of the semester and a post-test at the end. The tests were designed to measure a range of HOTS, including critical analysis, problem identification, and solution evaluation, using a set of open-ended and scenario-based questions [9, 13].
  - Survey Instrument: At the end of the semester, both groups completed a survey. The survey for the experimental group included questions about their frequency of AI use, their perceived helpfulness of the tools, and their concerns about dependency or ethical issues. The control group's survey focused on their problem-solving strategies and their perceptions of the challenges they faced.
- Qualitative Data:
  - Semi-Structured Interviews and Focus Groups: Following the post-test, a subset of 10 students from the experimental group participated in semi-structured interviews. These interviews were designed to elicit their experiences with AI, their perceived impact on their thought processes, and any ethical dilemmas they encountered. Additionally, one focus group was conducted with 5 students from each group to discuss their experiences and compare their problem-solving approaches. The interviews and focus groups were audio-recorded and transcribed for later analysis.
  - Contextual Data: The researchers collected and analyzed student artifacts from both groups, including project proposals, design sketches, and final reports. These artifacts were assessed for complexity, originality, and the overall quality of the problem solution. A rubric based on established criteria for evaluating design thinking and complex problem-solving was used to provide a consistent basis for evaluation [7, 12, 16].

Data Analysis

The collected data were analyzed using a combination of statistical and qualitative methods.

- Quantitative Analysis: Descriptive statistics (means, standard deviations) were calculated for the pre- and post-test scores for both groups. Paired t-tests were used to assess within-group changes from pre- to post-test, while independent t-tests were used to compare the performance between the experimental and control groups. The survey data were analyzed using frequency counts and correlation analyses to identify relationships between AI use, perceived effectiveness, and self-reported concerns.
- Qualitative Analysis: The transcripts from the interviews and focus groups were subjected to a rigorous thematic analysis. The researchers independently coded the data, identified recurring themes, and then collaboratively refined these themes to ensure inter-rater reliability [12]. The final themes were organized to reflect the students' experiences with AI, their cognitive processes, and their perspectives on ethical challenges.
- Epistemic Network Analysis (ENA): To provide a deeper look into the cognitive processes, we used Epistemic Network Analysis (ENA) to analyze the qualitative data. ENA is a quantitative ethnographic method that models and visualizes the connections between concepts (or codes) in a discourse [7, 15, 64]. We coded the interview transcripts and project artifacts for specific cognitive actions related to HOTS (e.g., "identifying problem,"

"synthesizing information," "evaluating solutions," "generating new ideas") and the use of AI tools. ENA was then used to generate network graphs that visually represent the strength and structure of these connections. This allowed us to compare the complexity and density of the cognitive networks of the AI-assisted group versus the control group, providing a visual representation of how AI may alter the very structure of thinking during complex problem-solving [7, 15, 64].

RESULTS

This section presents the findings from the mixed-methods analysis, beginning with the quantitative results from the pre- and post-tests, followed by the qualitative themes emerging from the interviews and focus groups, and concluding with the insights from the Epistemic Network Analysis.

Quantitative Findings

The analysis of the pre- and post-test data revealed a complex picture of AI's impact on HOTS. On the pre-test, both the control and experimental groups demonstrated comparable baseline levels of HOTS, with no statistically significant difference in their scores. However, the post-test results showed notable differences.

Table 1: Comparison of Pre- and Post-Test HOTS Scores by Group

Cognitive Skill Assessed	Control Group (M, SD)	Experimental Group (M, SD)	p-value	Effect Size (d)
Critical Analysis (Pre-test)	7.2 (1.5)	7.4 (1.4)	.612	0.13
Critical Analysis (Post-test)	**9.5 (1.1)**	8.1 (1.3)	**<.001**	1.15
Idea Generation (Pre-test)	6.8 (1.2)	6.7 (1.3)	.758	0.08
Idea Generation (Post-test)	8.2 (1.5)	**9.4 (1.2)**	**<.001**	0.86
Information Synthesis (Pre-test)	7.0 (1.4)	7.1 (1.3)	.821	0.07
Information Synthesis (Post-test)	8.5 (1.3)	**9.1 (1.1)**	**.015**	0.49
Solution	7.5 (1.6)	7.3 (1.5)	.543	0.13

Evaluation (Pre-test)				
Solution Evaluation (Post-test)	**9.1 (1.2)**	8.3 (1.4)	**.003**	0.61
Note: A paired t-test was used to compare pre- and post-test scores within each group, and independent t-tests were used to compare post-test scores between groups. Significant p-values (<.05) are highlighted in bold.				

The control group, which did not use AI, showed a significant increase in their overall HOTS scores from the pre-test to the post-test, particularly in areas related to critical analysis and evaluation. This suggests that engaging in complex problem-solving tasks without AI assistance is an effective method for developing these skills.

In contrast, the experimental group, which utilized AI, did not show a statistically significant improvement in their post-test scores for critical analysis and evaluation. However, this group did demonstrate a statistically significant increase in their scores related to idea generation and the synthesis of information. This indicates that AI may have served as a tool for rapid prototyping and information gathering, but potentially at the expense of developing deeper analytical and evaluative skills.

The survey results from the experimental group provided further insight. A strong majority of students (78%) reported that AI tools were "very helpful" for brainstorming and generating initial ideas. A smaller but still significant portion (55%) reported that AI helped them synthesize large amounts of information. However, when asked about the drawbacks, 62% of the students expressed concern about a potential over-reliance on AI. They noted that it was tempting to simply use the AI's output without fully understanding the process behind it, echoing the fears of cognitive offloading discussed in the literature [22, 65]. A substantial minority (41%) also raised concerns about the ethical implications, specifically the lack of transparency in how the AI generated its solutions.

Qualitative Findings: Thematic Analysis

The thematic analysis of the interviews and focus groups yielded four major themes that provided a deeper, more contextual understanding of the quantitative results. These themes are summarized in Table 2, with illustrative quotes.

Table 2: Key Themes from Qualitative Analysis

Theme	Description	Representative Quotes
AI as a "Partner" and a "Crutch"	Students viewed AI as both a collaborative tool that augmented their creativity and a support system that, if overused, could lead to dependency.	"It was like having a team member who was an expert on everything... so I wasn't just staring at a blank page." "Sometimes, it was just easier to ask the AI for the solution than to think it through myself. I didn't feel like I was learning as much as I should have been."
Efficiency vs. Understanding	Students appreciated the time-saving benefits of AI but felt it often came at the cost of genuine comprehension and deep learning.	"It saved me so much time... especially with the research part. I could get a summary of a dozen articles in minutes." "When I got the AI's answer, it felt like it was its understanding, not mine."
The Opacity of the "Black Box"	The lack of transparency in how AI generated its output led to a lack of trust and a feeling of disempowerment among students.	"It would give me a great answer, but I had no idea why it was the right answer. It just felt like I was trusting a black box."
The Call for Ethical Guardrails	Students demonstrated an awareness of ethical issues and expressed a need for clear guidelines and proactive governance of AI in education.	"Who owns the data we put into the AI? And what if the AI is biased? How would we even know?"

The thematic analysis directly supported the quantitative findings by providing a rich narrative of students' experiences. The dual nature of AI as a partner and a crutch reflects the trade-off between enhanced idea generation and the potential for reduced critical analysis. The tension between efficiency and understanding further contextualizes the observed differences in learning outcomes between the two groups.

Epistemic Network Analysis (ENA) Results

The Epistemic Network Analysis provided a visual and quantitative representation of the cognitive structures used by the two groups. The ENA models revealed distinct differences in the patterns of connections between cognitive codes. A summary of these findings is provided in Table 3.

Table 3: Summary of Cognitive Processes (ENA)

Group	Network Characteristics	Description
Control Group	High density, highly interconnected links between all HOTS codes. Strong connections between "critical analysis," "synthesis," and "evaluation."	A robust, integrated, and iterative problem-solving process. Cognitive effort was distributed across all phases of the task.
Experimental Group	Lower density, fragmented network. Strong but isolated connections between "idea generation" and "AI use." Weaker links between "idea generation" and other HOTS codes.	A compartmentalized approach to problem-solving. AI was used primarily for a specific phase (ideation), with less integration into critical and analytical thinking.

The ENA model for the control group showed a dense and highly interconnected network, with strong connections between codes such as "identifying problem," "synthesizing information," "evaluating solutions," and "generating new ideas." The network suggested a more integrated and iterative problem-solving process, where critical analysis was closely linked to both idea generation and synthesis. This "tightly woven" network points to a robust and holistic engagement with the problem.

In contrast, the ENA model for the experimental group (AI-assisted) presented a different structure. The network showed a strong, almost isolated connection between the code "generating new ideas" and the use of the AI tool. The connections between "idea generation" and "critical analysis" were notably weaker compared to the control group. This visual representation supports the qualitative finding that AI was primarily used for brainstorming and rapid ideation, while the critical, analytical phase of problem-solving was less integrated into the overall cognitive process. The network was less dense and showed a more fragmented approach, suggesting that AI may have influenced a more compartmentalized or "siloed" way of thinking, where parts of the process were delegated to the AI rather than integrated into a cohesive whole. This finding offers empirical support for the theoretical concept that AI is associated with disrupting the natural flow of higher-order thinking [7, 15, 64].

DISCUSSION

The findings of this mixed-methods study challenge the simplistic notion of AI as either a pure facilitator or a pure hindrance. Instead, they paint a nuanced picture of AI's dual role, suggesting that its impact is contingent on a variety of factors, including the specific cognitive skill in question, the nature of the task, and the user's intent. The evidence points to a complex dynamic where AI can empower some aspects of higher-order thinking while simultaneously posing a risk to others.

Our quantitative results demonstrate a clear trade-off. The control group, which engaged in the effortful process of problem-solving without AI, showed significant gains in critical analysis and evaluation skills. This outcome underscores the importance of struggle and independent cognitive effort in building these foundational HOTS [23, 29]. In contrast, the AI-assisted group excelled in areas of idea generation and information synthesis. This finding supports the argument that AI can function as a powerful tool for augmentation, enabling students to explore a wider "solution space" and work more efficiently [54, 59]. However, the lack of significant improvement in critical analysis and evaluation within this group suggests that offloading these tasks to AI may be associated with a cost to skill development. The data from the Epistemic Network Analysis visually reinforced this, showing that the AI-assisted group's cognitive processes were less integrated and holistic compared to the control group, who displayed a more cohesive and interdependent approach to problem-solving. This shift in cognitive structure is a critical finding, suggesting that AI's impact is not just on the outcome, but on the very way students think.

The qualitative findings provided the necessary context to interpret these results. Students’ self-reported experiences of AI as both a "partner" and a "crutch" directly maps onto the quantitative data. The efficiency AI provided was highly valued, yet the accompanying fear of losing a deeper understanding was palpable. This tension between productivity and intellectual depth is a central theme that educators must address. The students' candid discussions about the opacity of the "black box" and their concerns about ethical issues—such as transparency, data privacy, and bias—echo and provide powerful empirical support for the ethical gaps highlighted in the literature [5, 30]. The fact that students themselves are raising these concerns indicates that the conversation around AI in education needs to shift from a purely technical one to an ethical and pedagogical one.

These findings have several important theoretical and practical implications. Theoretically, the study contributes to our understanding of cognitive offloading and situated cognition [18, 20]. It provides empirical evidence that simply having access to an AI tool is not sufficient for learning; the tool must be integrated into a pedagogical framework that deliberately scaffolds its use to support, rather than supplant, the student's cognitive effort. The results suggest that for AI to be a true facilitator of HOTS, it must be used in a way that requires students to critically engage with its output, question its assumptions, and integrate its suggestions into their own understanding. This moves beyond a passive consumption of AI-generated content to an active and metacognitive use of the technology.

Practically, these findings provide actionable recommendations for educators and developers. For educators, the message is clear: the goal is not to ban AI, but to teach students how to use it as a tool for deeper thinking. Curricula should be designed to require students to go beyond the AI's output. This could involve having students justify an AI-generated solution, compare and contrast outputs from different AI models, or use AI for brainstorming but then be required to analyze and evaluate the ideas themselves. For EdTech developers, the findings highlight the urgent need to create more transparent and explainable AI tools. A "black box" that provides a final answer is less valuable for learning than a tool that can show its reasoning or the data it used to generate its solution. Incorporating participatory design with students and educators could lead to the creation of tools that are more pedagogically sound and ethically robust [5, 30].

This study also offers a strong and timely contribution to the conversation on AI ethics in education. The students' concerns around privacy, bias, and transparency are not theoretical but are felt and expressed in their daily learning lives. This calls for stronger proactive ethical governance from institutions and governments, a recommendation echoed in the literature [5, 30]. Ethical frameworks should not be an afterthought but should be embedded in the entire lifecycle of AI systems used in education, from data collection to deployment [5, 30]. Furthermore, institutions need to provide clear guidelines and training for both students and faculty on the responsible and ethical use of AI.

The study has several limitations. The quasi-experimental design, while robust, was limited to a specific student population and a particular type of complex problem-solving task. The findings may not be generalizable to other disciplines or age groups. The study was also conducted over a single semester, and a longitudinal study would be necessary to understand the long-term effects of AI use on cognitive development.

CONCLUSION

In conclusion, this research confirms that AI's impact is not a simple choice between a facilitator and a hindrance. It is both, depending on how it is designed and deployed. AI is a powerful tool for augmentation, capable of enhancing certain aspects of higher-order thinking, particularly in the creative and synthetic phases of problem-solving. However, without careful pedagogical design and robust ethical oversight, it also carries the significant risk of being associated with hindering the development of critical analysis and evaluation skills. The future of AI in education lies not in a binary decision to embrace or reject it, but in the deliberate and thoughtful integration of these technologies into a framework that prioritizes human-centered learning, ethical transparency, and the cultivation of intellectual independence. Future research should focus on longitudinal studies, the development of ethical AI frameworks for education, and empirical investigations into how different pedagogical interventions can effectively leverage AI to truly facilitate the development of higher-order thinking skills.

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