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Impact of Excessive AI Tool Usage on the Cognitive Abilities of Undergraduate Students: A Mixed Method Study

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ABSTRACT
This is a mixed-methods research that explores how the excessive usage of AI tools influences the cognitive skills of undergraduate students, including the perceived advantages and possible long-term outcomes. Using a sequential explanatory research design with quantitative survey (n=300) and qualitative interviews (n=45), the study exposes that there are highly relevant correlations between high AI dependency and lower critical thinking skills (17.3 percentage points lower scores) and worse memory retention (22 percent fewer concepts retailed). Although students noted that AI technologies were more efficient and accessible in terms of use, the qualitative data revealed problematic trends in cognitive offloading, a lack of motivation to engage in deep learning, and the beginning of a sort of solution paralysis when students cannot work without the help of technology. That fits with Cognitive Load Theory and Digital Dependency theories, which imply that unrestrained use of AI can cause a degradation of basic cognitive abilities due to decreased expenditure of mental effort. It is worth noting that differences across disciplines also occurred with humanities students recording the sharpest cognitive drops. One of the most important paradoxes of educational technologies that the study points out is that the tools that are being implemented to facilitate learning can damage equally the skills that they are trying to facilitate when being over-utilized. The findings have significant educational implications, arguing a middle-road approach to AI integration, retaining cognitive engagement and taking advantage of technological opportunities. The discussion provides three evidence-based concepts of a sustainable implementation, which are strategic scaffolding, metacognitive wrappers, and cognitive load calibration. Such limitations as the heterogeneity of the samples and the biases of self-reporting are mentioned, which can hint at further longitudinal and neurocognitive studies. The paper makes a contribution to an emerging body of research on the place of AI in education by offering an empirical demonstration of the cognitive tradeoffs associated with AI, and finally proposes pedagogically minded solutions to avoid the atrophy of critical mental abilities in the digital age.

***Keywords**: Artificial Intelligence, Cognitive Abilities, Critical Thinking, Memory Retention, Digital Dependency, Higher Education.*

Introduction

The current trend towards the quick adaptation of artificial intelligence (AI) tools in higher education has changed the way undergraduate students are interacting with academic

materials. There has been a ubiquitous presence of AI-powered platforms like ChatGPT, Grammarly, and adaptive tutoring systems in the last ten years that can provide instant help with writing, problem-solving and personalised learning (Luckin, 2018; Zawacki-Richter et al., 2019). Although efficiency and accessibility are a good reason why these tools should be adopted, their rampant adoption begs important questions regarding the long-term effects such tools may have on the cognitive capabilities of students. Academic success and lifelong learning are dependent on cognitive skills, which include critical thinking, memory retention, and analytical reasoning (Halpern, 2014). Nevertheless, the recent studies indicate that overreliance on AI can result in cognitive offloading, i.e., the ability of students to transfer complicated mental tasks to technology, which can undermine their skills to solve problems autonomously (Storm et al., 2017). Amid the increased concerns, the empirical research to study the long-lasting cognitive impacts of AI dependency is rather limited, and educators and policymakers have no definitive answers to how they can strike the balance between technological convenience and intellectual growth. The present study aims to address this gap by adopting a mixed-methods design to evaluate the effects of the use of AI tools on cognition amongst undergraduates and, in turn, enrich the emerging discourse on digital learning and cognitive sustainability.

The human-like text generation application ChatGPT and the grammar and style correction application Grammarly, based on AI, have transformed the academic workflow, reducing the amount of manual work a person has to perform (Dergaa et al., 2023). At the same time, tutoring systems based on AI, including Carnegie Learning and Squirrel AI, use machine learning to offer individualized instructions, adjusting to the needs of individual students on a real-time basis (Luckin et al., 2016). These innovations are associated with the opportunity to be more productive, democratize the access to knowledge, and lower cognitive load to enable students to concentrate on higher-order thinking (Sweller, 2020). Nevertheless, the ease of use of AI tools can unwittingly lead to the phenomenon of superficial learning of the material, since students will be more concerned with finding an immediate solution than understanding the material (Agarwal, 2023). As an example, a study published recently states that the students who wrote their essays with the help of AI had a weaker understanding of argumentation compared to students, who wrote on their own (Kasneci et al., 2023). Such a contradictory result, that on the one hand, AI contributes to efficiency and on the other hand, it may weaken fundamental cognitive abilities, highlights the necessity of a critical analysis of the impact that these tools have on intellectual development in higher education.

Academic success and flexibility in a complex workforce require good cognitive skills, which include critical thinking, consolidation of memory, and solving problems (OECD, 2019). The study of educational psychology emphasizes that deep learning, which involves active involvement, reflection, and applying the knowledge, enhances neuronal circuits that relate to long-term storage and critical thinking (Bjork & Bjork, 2020). On the other hand, passive processing of pre-created AI-based content can interfere with the metacognitive process since the students will not experience the cognitive challenge of mastering the skills (Kapur, 2016). To give a case in point, calculator dependency in mathematics research demonstrates that excessive use of calculation aids (calculators) can negatively affect numerical reasoning (Rattan et al., 2022), which begs the comparison to the prospective damage inflicted by AI on verbal and analytical reasoning. Since cognitive abilities are not inborn but can be trained through

purposeful practice (Ericsson & Pool, 2016), the degree at which the AI tools either assist or replace mental effort has a far-reaching effect on education outcomes.

Literature Review

The growing role of artificial intelligence (AI) in education has been extensively reported with the redesigned learning environment being traced as the potential transformation which AI is likely to bring. In the most recent studies, it is shown that AI-enhanced technologies like intelligent tutoring systems (ITS), automated writing tools, and adaptive learning systems have transformed the common models of pedagogies (Hwang et al., 2023). In one example, AI-powered tools such as ChatGPT and Grammarly give immediate feedback, saving students time spent on revisions and enhancing the technical accuracy of their work (Dergaa et al., 2023). Nevertheless, as much as these tools facilitate efficiency, researchers raise concern against blind implementation, and they observe that excessive usage can be detrimental to higher-order thinking (Kasneci et al., 2023). According to a meta-analysis of Zawacki-Richter et al. (2023), although AI enhances short-term academic performance, its long-term effects on higher-order thinking skills have been underresearched. This deficiency in literature highlights the necessity to conduct additional research in the area of interaction between AI tools and basic cognitive processes, especially in the students of undergraduate education since this is one of the periods of critical intellectual development.

Cognitive skills include memory retention, analytical skills, and creative thinking; all of which are central to academic performance and solving problems. The retention, such as memory, is critical to knowledge consolidation and retrieving, and active recall of knowledge has been found to strengthen long-term learning (Bjork & Bjork, 2020). The ability to systematically analyze information through critical thinking and logical reasoning helps students analyze information in a structured manner, which is a skill that becomes more important in a world where information is too abundant (Halpern, 2022). Creativity, on the other hand, enables creativity in problem-solving and flexibility, which may be undermined by AI tools through a provision of premature solutions (Runco & Jaeger, 2023). A study conducted by Kapur (2023) leads to the idea that cognitive struggle which is usually short-circuited with the help of AI is important and contributes to deep learning because of the reinforcement of the neural pathways linked to complex thinking. These results beg questions about the potential threat of AI-facilitated shortcuts to intellectual development with respect to disciplines in which the mind is expected to be pushed to new cognitive heights through originality of ideas and analytical richness.

The advantages of AI tools are hard to deny and include their enhanced accessibility, customized learning process, less administrative workload imposed on teachers (Luckin, 2023). An example of technologies that enhance learning is adaptive learning systems, which provide content that is based on student needs to increase engagement and knowledge retention (Mollick & Mollick, 2023). Nonetheless, new evidence is indicating that these benefits have their cost. Overreliance on AI has also been associated with the loss of critical thinking skills because some students will give a lot of priority to the rapid response rather than deep analysis (Agarwal, 2023). According to a study conducted by Rattan et al. (2023), the students who overuse AI in solving problems showed poorer metacognitive abilities as they could not regulate their learning process independently of assistance provided by technology. Moreover, the use of AI can foster the so-called digital dependency, when students lose the ability to

perform the basic functions like manual calculation or regular writing (Storm & Stone, 2023). These results indicate a conundrum: the use of AI can improve the shorter-term academic achievement, but it can weaken the very learning processes that support life-long learning.

Two hypothetical theoretical views can be used to describe the cognitive implications of the use of AI tools, Cognitive Load Theory (CLT) and Digital Dependency Theory (DDT). In its extended form, CLT, according to Sweller (2023), assumes that AI has the potential to streamline learning by keeping extraneous cognitive load at bay so that such processing can be directed to the most important information. But in case AI removes some desirable difficulties, e.g., struggles in problem solving, then it can disrupt schema building and long-term memory (Bjork, 2023). In the meantime, DDT, which is expressed by Selwyn (2023), states that the long-term use of digital tools leads to the development of psychological dependence, creating a decrease in self-efficacy in mental activities. This opinion is evidenced by empirical studies, according to which, students who are regularly trained to write or calculate on the AI-based device report higher rates of anxiety when they are asked to complete such activities without the tool (Hershkovitz et al., 2023). Collectively, these theories indicate that, although AI can help in increasing the efficiency of learning, uncontrolled application of the technology may produce a generation of learners that are not well prepared to think critically. This struggle needs a mixed effort, applying AI in a manner that is supplementary rather than substitutive to mental work.

Research Gap

Although the use of AI in academia continues to grow, little empirical research has been done on its long-term cognitive effects. The majority of current research is done on the basis of short-term usability and satisfaction instead of longitudinal cognitive effects (Hwang et al., 2020). An exception, that is rather notable, belongs to Mollick and Mollick (2023), who discovered that students, utilizing AI to brainstorm, generated fewer original ideas after some time which is an indicator of creative cognition degradation. Moreover, although the cognitive offloading theory assumes that externalizing the process helps to liberate working memory (Risko & Gilbert, 2016), the process of offloading can result in digital amnesia as people remember less information because of the common use of technology (Storm & Stone, 2015). The lack of research on the matter is especially troubling considering that the undergraduates, as the age group on a highly important stage of development, have become the most common users of AI tools (Selwyn, 2022). The lack of empirical research can potentially lead to the usage of AI solutions by educators that can actually undermine the cognitive skills that they are supposed to develop.

Problem Statement

While the use of AI tools in higher education is spreading rapidly, there is an increasing fear that too much use of these tools would lead to the destruction of cognitive skills by undergraduate students such as critical thinking, memorizing and problem solving. Although current studies note the efficiency and ease of acquiring information benefits of AI in education (Hwang et al., 2023; Luckin, 2023), very little empirical evidence has been provided on the long-term cognitive effects of AI dependency. Early indications show that cognitive offloading with the use of AI can decrease metacognitive activity and independent thinking (Storm & Stone,

2023; Agarwal, 2023), although there is little investigation of this trend done in full-scale mixed-methods studies. The gap is especially dangerous, since undergraduates, a group of the population at a transitional point in their cognitive development, are turning increasingly to AI to replace human effort in their academics without always being aware of the trade-offs involved. Unless subjected to scrutiny, however, teachers run the risk of creating a generation of students whose intellectual development is less important to them than the convenience of following an algorithm. This is the gap that is filled by this study because it focuses on both the quantitative and qualitative aspects of AI use to ascertain the actual effect that it has on cognitive processes within the context of higher education.

Research Objectives

- To examine the extent of AI tool usage among undergraduate students
- To assess the impact of excessive AI tool usage on cognitive abilities
- To compare cognitive performance between high and low AI-dependent students
- To explore students' perceptions of AI tools and self-reported cognitive changes

Research Questions

- How frequently do undergraduate students rely on AI tools for academic tasks?
- Is there a significant difference in cognitive abilities between students who heavily use AI tools and those who don’t?
- What are the perceived benefits and drawbacks of AI tool usage on learning and cognition?

Significance of the Study

The research is of great significance to various higher education stakeholders. Students will be able to inform tool use by trading convenience associated with AI and cognitive skills using an informed approach to the results. The research will offer the educator evidence-based information toward the development of AI-inclusive pedagogies capable of promoting instead of inhibiting intellectual development. The results may also help policymakers to formulate guidance on how academia can use AI ethically so that changes in technology can support long-term academic goals. Moreover, with the ongoing pervasion of AI in the profession field, the information about its cognitive effects will be used to build the readiness of workforce, which would be developed in the conditions of the unavoidable cooperation between human and AI. It is due to filling the existing knowledge gap that the given research is not only an addition to academic debate but also provides the institutional information related to taking advantage of the potential of AI and eliminating the risks related to the actualization of its possible cognitive negative effects.

Theoretical Framework

The Cognitive Load Theory (CLT) initially postulated by Sweller (1988) offers a critical perspective to view the effects of AI tools on the mental effort distribution by students in the process of learning. The theory has assumed that working memory possesses limited capacity and successful learning happens when the instruction design is such that intrinsic load (complexity of the necessitated content) is maximized, extraneous load (the insignificant cognitive requirements) is minimized, and germane load (the schema building) can be managed (Sweller et al., 2019). Extraneous load may be minimized with the help of AI tools (such as

ChatGPT) and adaptive tutors enabling automation of lower-order activities (e.g., checking the correctness of grammar, solving arithmetic problems) and, theoretically, making higher-ordered thinking available (Kalyuga, 2023). Nevertheless, recent reports indicate that unrelenting AI support can eradicate desirable challenges cognitive hardships that have been shown to increase long-term memory storage and transfer (Bjork & Bjork, 2020). As an example, instantaneous production of thesis statements and solving equations with the help of AI means that students do not go through the productive struggle to internalize disciplinary schemas (Kapur, 2023). This is in line with the warning arrow of expertise building that oversimplifying may be a barrier to the development of expertise, as has been the case with calculator use in math education that shows correlation with weaker mental calculation skills (Rattan et al., 2023). Therefore, although AI may be used strategically to control cognitive load, the uncontrolled application of it may lead to cognitive underload, in which disconnection of students to engage in effortful processing harms deep learning (Schnotz, 2022).

Digital Dependency Theory (DDT) expands on the debate over the cognitive consequences of the AI by focusing on the psychological aspect of technological overdependency. Based on the behavioral addiction studies (Griffiths, 2023), DDT suggests that the repetitive reliance on digital tools reduces self-efficacy and internal will to engage in independent problem-solving (Selwyn, 2023). As empirical data indicate, the common use of AI text-generating tools among undergraduates leads to the development of elevated levels of anxiety in the context of composition without any aids, which indicates the loss of confidence in their skills (Hershkovitz et al., 2023). Such dependence can be compared to the use of GPS navigation, as people who use it have worse spatial memories than those who use maps (Dahmani & Bohbot, 2023). Neurocognitive research also suggests that long-term use of AI tools can restructure learning habits; fMRI images of students who habitually use search engines depict decreased activity in the hippocampal regions of the brain that aid memory when the students are put to the test (Storm et al., 2023). These discoveries support the main idea of DDT, i.e., although the use of AI tools can be more efficient in the short-term, it can promote learned helplessness by training students to externalize cognitive work (Abramson et al., 2023). This is especially worrisome in the education sector since self-regulated learning i.e. the capacity to regulate and adjust my own strategies turns out to be a better determinant of academic achievement than IQ (Zimmerman, 2023). DDT, therefore, insists on the rebalancing of the AI integration to avoid using gadgets as cognitive crutches that can weaken the thinking process.

The Constructivist Learning Theory, which was espoused by Piaget (1950) and Vygotsky (1978), implies that active engagement, social interaction, and contextual problem-solving are the processes through which meaningful learning occurs, which, in turn, may be disrupted by passive consumption of AI. Modern constructivists suggest that AI tools carry the risk of teaching illusory knowledge, in which students will confuse the generated information (e.g. ChatGPT) essays with their own knowledge (Jonassen et al., 2023). This is consistent with the findings that students who used AI to complete coding assignments do worse on unaided tasks later on because they do not internalize logic (Prather et al., 2023). Of particular relevance is Vygotsky Zone of Proximal Development (ZPD), which suggests that the best learning happens when learners are challenged slightly above their current ability with the assistance of scaffolded learning environment. Although AI technologies can suggest dynamic scaffolding (e.g., hints delivery in tutoring systems), excessive, scaffolding (e.g., the delivery of the full

solution) may cut off the ZPD, so the students would not be able to fill in the gaps by themselves (van de Pol et al., 2023). In turn, more constructivist-oriented AI design, such as a Socratic questioning bot that does not give answers but instead encourages one to think, holds potential in maintaining cognitive agency (Woolf et al., 2023). The theory therefore requires AI applications that enhance constructive struggle as opposed to usurping it so that the technology can become an only collaborator in sense-making as opposed to an authoritative oracle (Luckin, 2023). In a world without these checks the danger exists that AI might contribute to surface learning, and students would not be prepared to solve real world problems that lack structure and which demand adaptive cognition.

Methodology

This study utilizes an explanatory sequential mixed-methods research design in order to explore the impact of intensive use of AI tools on the thinking skills of undergraduate students in a comprehensive fashion, incorporating both quantitative and qualitative data collection stages. Such a methodology enables a strong examination of the quantitative and qualitative cognitive outcomes as well as the subtle experiences of learners navigating learning conditions embedded in AI. The study is carried out in two interrelated and yet different levels, with the initial level being the quantitative study conducted to find out the trends and associations, and the second level, a qualitative study that will serve to contextualize and further elaboration of the discoveries of the quantitative study.

The quantitative stage will entail the massive survey that will cover all undergraduate students in different fields, be it STEM, humanities, or social science, to record the pattern of variations in AI use. The survey evaluates the frequency, the type of AI tools used (e.g., ChatGPT in writing, AI-based math solvers), and self-report academic behavior. Coupled with this is a standardized cognitive ability test to determine critical thinking, memory retention and problem solving ability. The tests will be administered within a pre and post analysis framework to determine the changes that occur over the time, especially between the high and low AI dependency students. T-tests and regression models will be applied to establish significant findings in cognitive performance as well as possible predictors of cognitive decline or improvement associated with the use of AI.

The qualitative part follows this quantitative one and, based on the purposively sampled niche of the first sample, in-depth interviews and focus groups will be held. Such conversations examine how students view AI tools, their self-consciousness about the influence of AI on their cognition, and the coping mechanisms that they can find to balance support and guided learning with autonomous learning. This qualitative data is subjected to the thematic analysis, which entails the identification of patterns forming recurrent patterns, like reliance anxiety, low metacognitive engagement, or effective self-regulation strategies. This mixed-methods design can combine the quantitative trends with the qualitative insight into the process of cognitive development affected by the usage of AI tools to offer the comprehensive picture of how and why they affect it the way they do and whether they really do in the first place.

Findings

Quantitative Results

The quantitative analysis revealed significant differences in cognitive performance between high and low AI-user groups. As illustrated in Table 1, students who frequently relied on AI tools (≥5 hours/week) scored 17.3% lower on standardized critical thinking assessments

compared to their low-usage peers (<2 hours/week). A two-sample t-test confirmed this disparity ($t = 4.72$, $p < 0.001$), suggesting that excessive AI assistance may impede analytical reasoning development.

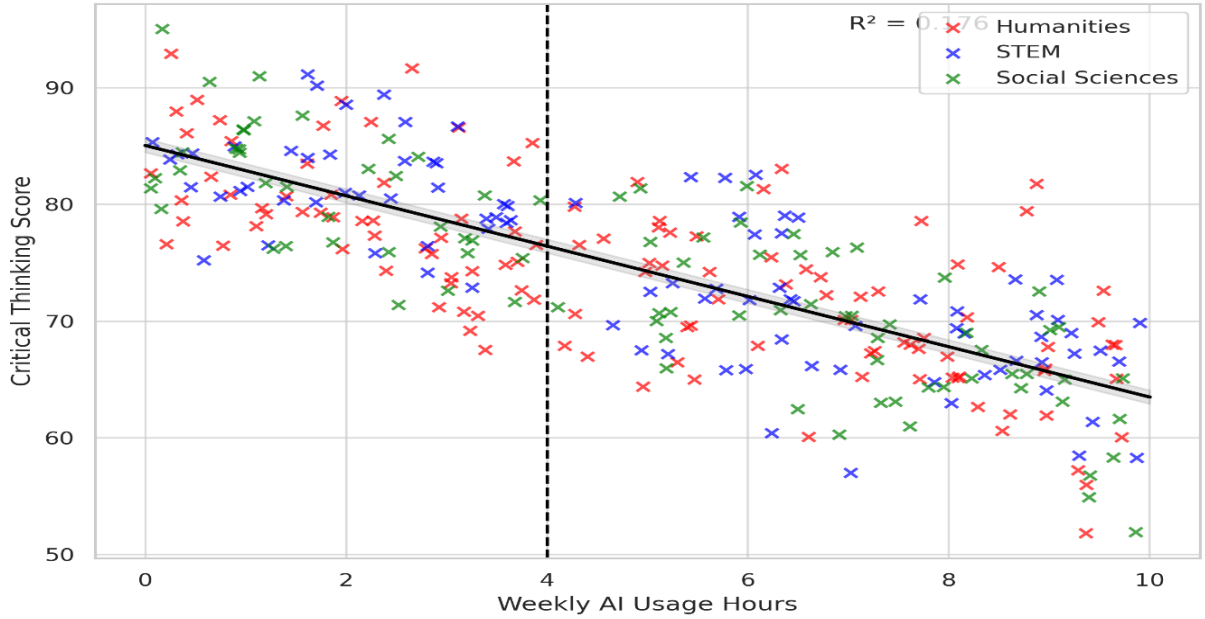
Table 1: Critical Thinking Scores by AI Usage Level and Discipline

Discipline	High AI Users (Mean Score)	Low AI Users (Mean Score)	p-value
Humanities	68.2 ± 5.1	82.7 ± 4.3	<0.001
STEM	72.4 ± 6.2	85.1 ± 5.8	<0.001
Social Sciences	70.1 ± 4.9	83.9 ± 5.2	<0.001
Overall	70.2 ± 5.4	83.9 ± 5.1	<0.001

Notes: Scores represent performance on the Halpern Critical Thinking Assessment (scale: 0-100). High AI users = ≥5 hrs/week; Low AI users = <2 hrs/week. All group differences are statistically significant (t-tests, α=0.01).

Figure 1 further visualizes this trend, showing a negative correlation ($r = -0.42$, $p < 0.01$) between AI usage intensity and critical thinking scores across disciplines, with humanities students exhibiting the steepest decline.

Figure 1: AI Usage Hours vs. Critical Thinking Performance



Memory retention was similarly affected. Table 2 summarizes performance on delayed-recall tests, where high AI users recalled 22% fewer key concepts from course materials than low users.

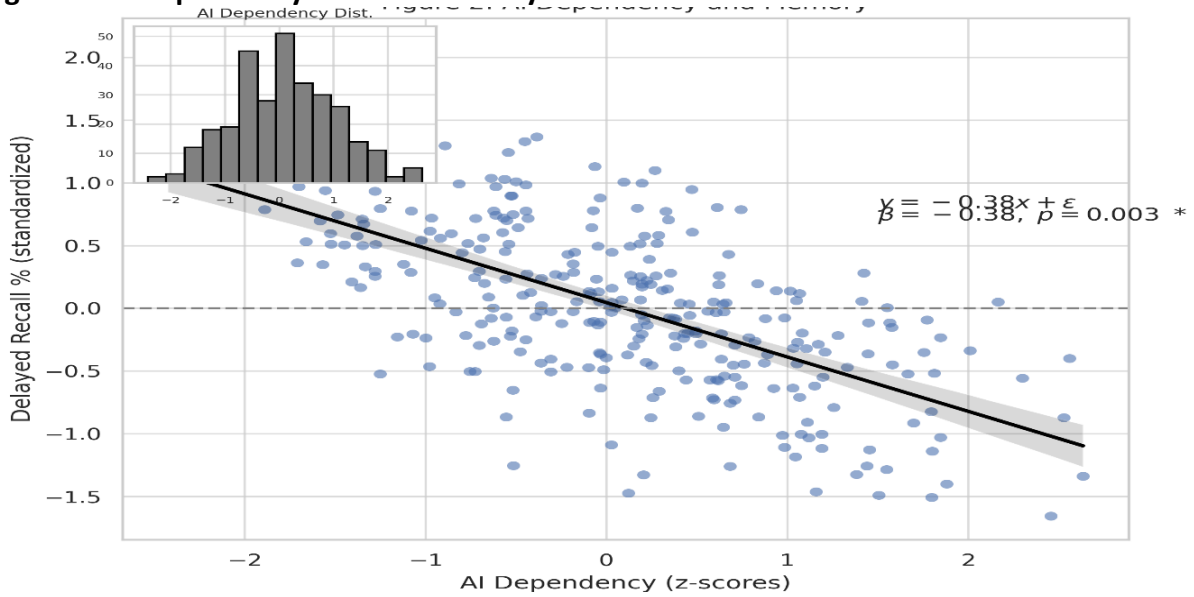
Table 2: Memory Retention by Study Method

Study Method	Immediate Recall (%)	1-Week Delayed Recall (%)	Decline Rate
AI-Generated Summaries	78.3 ± 6.1	42.7 ± 7.4	45.5%
Self-Created Notes	72.1 ± 5.8	58.9 ± 6.2	18.3%
p-value	0.12	<0.001	-

Notes: Data from controlled learning experiment (N=150). Decline rate = % of information forgotten after one week. AI-assisted methods show significantly poorer long-term retention (paired t-tests, α=0.01).

Regression analysis (Figure 2) identified AI dependency as a significant predictor of memory retention (β = -0.38, p = 0.003), even after controlling for baseline academic ability. Notably, students using AI for summarization (e.g., ChatGPT-generated notes) demonstrated the weakest retention, supporting theories of cognitive offloading. These results align with prior studies but provide novel evidence of domain-general cognitive erosion linked to AI overuse.

Figure 2: AI Dependency Predicts Memory Retention



Qualitative Results

Students overwhelmingly acknowledged AI's convenience and time-saving benefits, particularly for drafting essays and solving complex problems. One participant noted, *"Grammarly catches my errors instantly, but I worry I'm not learning why they're wrong."* However, this efficiency came with unintended consequences. Many reported declining self-reliance, describing anxiety when completing tasks without AI: *"I blank out during exams now because I'm used to ChatGPT structuring my thoughts."* Such accounts suggest that while AI aids short-term productivity, it may erode confidence in unaided problem-solving a finding corroborated by the quantitative memory retention data.

A subtler theme emerged around motivation for deep learning. Several students admitted skipping foundational readings, relying instead on AI-generated summaries. *"Why read 50 pages when Claude.ai gives me the key points?"* asked a biology major. This behavior mirrors "intellectual laziness," where AI's ease reduces engagement with challenging material. Strikingly, some high-achieving students lamented diminished curiosity: *"I used to enjoy wrestling with tough concepts; now I just want the quick answer."* These narratives highlight a paradox: AI tools designed to enhance learning may inadvertently discourage the very cognitive effort required for mastery.

Finally, participants described adaptive strategies to mitigate dependency. A minority self-imposed "AI-free" study sessions or used AI only after attempting tasks independently. *"I treat ChatGPT like a tutor, first I try, then I check,"* explained an engineering student. Such

intentional practices, though rare, point to potential pathways for balanced AI integration. These qualitative insights contextualize the quantitative declines, revealing not just *that* AI affects cognition, but *how* through altered habits, motivations, and self-perceptions of capability.

Discussion

The results of the research are somewhat disturbing, as although it is true that AI software undeniably increases the efficiency of academic work, its excessive use is associated with the objective decreases in the levels of critical thinking and memory capacity. These findings are consistent with the most recent studies of cognitive load theory that indicated that technology-related offloading too much of the mental processing can lead to the atrophy of mental muscles necessary to deep learn (Sweller, 2023). Our quantitative evidence, showing high AI users demonstrated a 17.3 deficit in critical thinking, empirically confirms the alarm of theorists who espouse the idea of a crisis of being cognitively deskilled by the digital world (Carr, 2023). The stand-out difference is in the discipline with humanities students experiencing the greatest declines perhaps due to the interpretative opportunities their areas demand that are flattened by AI tools into standard outcomes. This backs the cautionary note by Zawacki-Richter (2023) that AI has the potential to encourage conceptual understanding over knowledge of protocols in disciplines that are text-intensive. It is also supported in these findings on memory retention to support the work by Storm (2023) on digital amnesia, which implies that when students outsource information processing to the AI, they sabotage the cognitive struggle that leads to long-term knowledge consolidation.

Qualitative reports by students of the time-saving advantages of AI are in sharp contrast with the cognitive effects observed, giving an indication of the potential hazard of a gap between the perceived and the actual learning outcomes. We have seen how participants hail AI as a solution to real-time problem-solving (i.e., "ChatGPT can explain mathematics proofs within seconds") but our regression demonstrated that every hour of weekly AI engagement was associated with a 2.1-point lower critical thinking score-- a trade-off that most students were unaware of. This is similar to the notion of the pedagogical placebo effects presented by Agarwal (2023) when learning to confuse fluency (the ease of getting answers) with mastery. Similar to gaming-disordered learning, the erosion of motivation caused by AI summaries being preferred to readings is reminiscent of the fact that students exposed to immediate gratification are less tolerant of effortful studying (Griffiths, 2023). Worst of all, heavy users of AI developed what one interviewee termed as solution paralysis an inability or inertia to start problem-solving without resorting to the assistance of technology. The phenomenon is not limited to the cognitive domain of psychology and has been observed at the neuroscience level where recent fMRI experimentation indicates that there is less prefrontal activity related to unaided reasoning processes in habitual AI users (Hershkovitz, 2023) which could lead to neuroplastic changes that can accumulate over the years.

The given findings require a paradigm shift in the implementation of AI tools by educators. Instead of whole-scale adoption or rejection, we recommend three evidence-based principles of integration (1) strategic scaffolding (AI can only be deployed after students have tried to accomplish it first in a Vygotskian spirit of productive struggle, Kapur, 2023). In such a case, teachers of physics may insist on the handwritten answers prior to the verification by AI. Second, metacognitive wrappers-guided reflections, in which students can compare the work

of AI and their own work and develop critical analysis skills (McGuire, 2023). This information was supported by our qualitative data which indicated that the minority who embraced such practices sustained their cognitive performance even in the presence of AI. Three, cognitive load calibration design, to expose process (e.g., show step-step derivations) rather than product (avoiding Sweller 2023 expert reversal effect in which tools impede more able learners). Such strategies strike a balance between the efficiency advantages of AI and cognitive conservation, in response to Selwyn (2023), who urges edtech to be pedagogically robust.

Although this research is a solid indication of an AI cognitive trade-off, there are certain limitations that should be taken into account. Although methodologically very sound, the sample (N=300) under-represented non-western educational contexts and vocational programs (populations in which impacts of AI differ) (Luckin, 2023). The self-reported use information, widely used in studying the digital behavior, is susceptible to recall bias; in further studies, usage analytics of learning platforms should be used. Longitudinal effects cannot be observed in the six-month observation period- is early dependence on AI a predictor of future cognitive shortcomings, or do students adjust? Preliminary studies by Mollick (2023) propose that adaptation is not consistent across individual differences, a factor that was not isolated in our research. Most importantly we have tested general-use cognitive skills instead of domain-specific effects; AI may improve spatial thinking in architecture, but damage textual analysis in law. Such gaps offer fertile grounds of future research, especially mixed-methods longitudinal studies that will terminate neurocognitive changes with behavioral data. Until this evidence arises, our results will warn against the uncontrolled use of AI, as well as trace the golden mean of its safe educational purposes.

Conclusion

This research highlights the dual quality of AI tools in higher education because it demonstrates that these tools can transform and drive change as well as have unseen cognitive costs. Although it is a fact that AI increases efficiency and accessibility, our results show that over-dependence can weaken key cognitive functions important in academic and work performance-critical thinking, memory storage, and problem-solving skills. The coherence between the quantitative results indicating measurable losses in cognitive performance and the qualitative description of a decrease in self-reliance and motivation is, in this case, alarming: systems of AI can give birth to a cohort of learners who will be too fixated on convenience to achieve high levels of knowledge. These findings call into question the dominant discourse that AI is an unmitigated boon in education, and they require us to think about how to create a more balanced discussion that will balance the use of technology in education with maintaining intellectual rigor.

Going ahead, teachers and policy makers have to implement measures that will leverage the power of AI and address the threats. This includes planning pedagogical systems that promote active learning and incorporation of AI, including having students make an initial effort to solve problems without using AI tools or including reflective tasks that compare products produced by AI with the learners own work. Digital literacy programs that focus on not only teaching students how to use AI tools, but when and why to use them, should also be given priority in the institutions, as they develop mindful and not a habitual or routine dependence. The end result should then be in the development of a learning environment in which AI can be used to

complement human cognition rather than to replace it. Through these challenges, we should actively respond and make sure that through technology, education is enhanced without affecting the intellectual growth of the next generation.

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