Medha Yadav, 2026, 14:4
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

Does Cognitive Offloading to AI Systems Influence Metacognitive Awareness and Critical Thinking Ability

Medha Yadav[1], Yash Kapoor[2], Aditya Arora[3], Ankush Rana[4], Priyanka Yadav[5]

[1]Department of Artificial Intelligence and Data Science, HMR Institute of Technology and Management, GGSIPU, New Delhi, India

[2,3]Department of Computer Science and Engineering, HMR Institute of Technology and Management, GGSIPU, New Delhi, India

[4,5]Department of Management, HMRITM, GGSIPU, New Delhi, India

Abstract- This study explores how dependence on Artificial Intelligence (AI) affects critical thinking, with AI Dependency and Metacognition acting as key mediating factors. In today's world AI tools are becoming more common in educational and professional environments such as teaching and in offices as well , leading individuals to depend on AI for a greater number of cognitive tasks. Although this trend simplifies many angles of life, it also raises concerns about a possible decline in our ability to think independently. The paper reviews existing research to assess how AI dependence impacts cognitive engagement and decision-making processes. While AI can enhance productivity and learning, a very excessive reliance on it may lead to reduced cognitive demands and hinder the development of critical thinking abilities. It is also suggested that metacognition plays a vital role in critical thinking because of its function in overseeing, assessing, monitoring and regulating cognitive processes such as problem solving, learning etc. A conceptual model is presented that includes Metacognition, Cognitive Offloading, AI Dependency, and Critical Thinking. This framework demonstrates both direct and indirect connections between Cognitive offloading and Critical thinking. It indicates that metacognition has a positive effect on reflective and analytical thinking. These findings highlight the importance of purposeful usage of AI and the cultivation of metacognitive skills to improve critical thinking in this digital age.

Keywords: Cognitive Offloading, Critical thinking, Metacognition, AI Dependency, Decision making.

I. INTRODUCTION

The fast-paced advancement of artificial intelligence (AI) technology has brought substantial changes in how people obtain, understand, and use knowledge [1] [2]. Nowadays, AI systems are gradually entering people's daily cognitive activities [1]. Tools like ChatGPT and GitHub Copilot help people deal with various problems, write, program, and make decisions [1]. People can obtain massive knowledge and automatic help immediately, which greatly improves their working efficiency [1]. Not only work-related scenarios but also daily life and learning see AI's increasingly significant role in supporting human cognition [3].

AI might help us with our mental limits in the future, reducing mistakes, faulty conclusions, and making better decisions [2]. But how far are we prepared to surrender aspects of our mental self-reliance and autonomy, and how much of our brain's grey matter and accrued wisdom may remain underspent and under appreciated from underuse as we develop AI "masters" that are superior problem solvers, can reason better, and can supplant us in spotting significant trends, novelties, and opportunities? An explanation for this is cognitive offloading, a process in which people use tools or other systems to lessen their cognitive load [4].

However, with the emergence of generative AI systems, cognitive offloading exceeds the limits of memory and simple cognitive steps to more advanced types of reasoning. Even with all of these amazing advancements, human thinking is still necessary for reviewing what AI produces; people must assess data quality, trustworthiness, and contextual appropriateness [2] [3]. Taking all of the previous into consideration, human-AI collaboration efficiency depends not only on how advanced AI

tools are but also how the human mind works [5]. More specifically, one process that is of interest is metacognition [6]. Metacognition is defined as one knowing how they learn by planing, monitoring, and evaluating their performance while trying to solve a problem or learn something new [6][7].

It is the process of evaluating how well you understand what you are trying to accomplish and altering your actions to try to learn or solve something as effectively as possible [7]. By having a higher metacognitive thought process, people are able to think about their thinking and choose the best course of action to take [7][8]. One skill that goes hand in hand with metacognition is critical thinking. Critical thinking can be defined as the skill of thinking about what information you have, evaluating evidence, and making conclusions [9]. Critical thinking and metacognition have been thought to be of high importance to help us learn, solve problems, and become experts in our field [9][10]. Research has shown that people who metacognate and think critically more often will have higher academic and real-life performance than people who do not think this way [10][11].

According to co-evolution theory, the more we enhance our metacognitive skills and critical-thinking skills, the better we are at using cognitive artifacts such as technological advancements like AI [11][12]. As we get better at using these cognitive artifacts, we are able to perform tasks better and faster. [12] Even though AI is being used more frequently in the classroom and work setting, there has been little research done on its effects on cognition. This includes how AI can help students think critically and metacognate [13]. This is an issue since students are using AI-based tools to help them with class work more frequently [13][14].

Fig. 1 illustrates the relationships between cognitive offloading, AI dependency, metacognition, and critical thinking within human–AI interaction. Cognitive offloading to artificial intelligence (AI) is the main driver for the emergence of AI dependency.

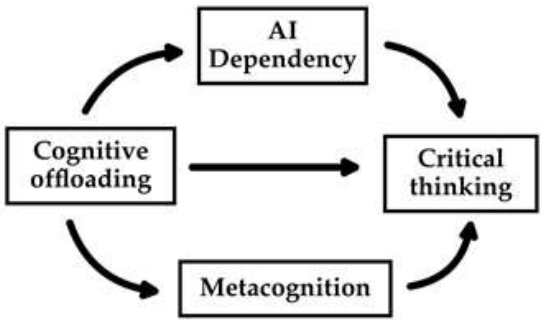

Figure 1. Conceptual Model Of The Relationships Between Cognitive Offloading And Critical Thinking, Including Mediation By Individual Differences (Ai Dependency, Metacognition)

As people increasingly solve, search information, make decisions etc. by distributing the workload of their cognition to AI, they develop AI dependency, because AI systems can deliver solutions and responses more efficiently and with greater accuracy than humans. Greater cognitive offloading consequently results in higher AI dependency. The model portrays a complex cyclic structure of connections within AI-assisted environments, delineating how cognitive offloading increases reliance on AI, modulates levels of metacognition, and consequently affects critical thinking abilities, which in turn are affected by the level of cognitive offloading.

II. LITERATURE REVIEW

II.A AI Dependency

This term is used to define the degree to which an individual depends on AI systems in performing cognitive tasks like problem-solving, decision-making, and information processing[32]. The more an individual depends on AI systems, the more they do not engage their own cognitive capabilities in performing tasks and relying on the results provided by AI systems.

II.B Critical Thinking

This is defined as the ability to analyze and interpret information before coming up with conclusions. This involves using logical reasoning and making informed decisions rather than relying on information provided on its own face value[33].

II.C Metacognition

This term is used to define an individual's ability to monitor and control their own cognitive processes. This includes planning how to approach a task, how they understand it in the process, and how they evaluate it in order to improve their performance in the future[34].

II.D Cognitive Offloading

This term is used to define the process of using external devices like AI systems to reduce mental effort in performing tasks. This reduces mental effort but may impair an individual's ability to think deeply and solve problems independently [35].

RELATIONSHIP WITH VARIABLES

II. E. Cognitive Offloading and Metacognition: Implications for Learning and Self-Regulation

There is strong evidence that metacognitive processes and cognitive offloading behaviors are related in both ways. Gilbert's experiments were done to demonstrate offloading strategies that are heavily influenced by metacognitive beliefs about one's ability to carry out cognitive tasks in addition to objective memory ability[17]. Even at actual performance levels, people who had lower self-confidence tend to exhibit greater offloading tendencies[17]. This pattern was seen consistently in both natural environments and laboratory patterns where self-generated intentions are integrated into routine tasks[17]. Interventions involving metacognitive training have the potential to maximize offloading choices. Gilbert and colleagues' experiments that were pre-registered showed that, in comparison to control conditions, combining metacognitive predictions with calibration feedback significantly results in decreasing both metacognitive bias and reminder-setting bias[17].

Research on the use of external aids to reduce cognitive demand reveals a strong correlation with metacognition, that is, "thinking about your own thinking" [18]. An individual's decision to cognitively offload tasks is mostly influenced by their metacognitive beliefs about their internal abilities; for instance, lower confidence in one's memory (rather than personality) is linked to a greater tendency to use external reminders[18][19].

Research shows that people don't always choose the best way to rely on tools or help. This happens because they often misjudge how good their own memory actually is due to metacognitive biases, which leads them to make poor or excessive offloading decisions—even when internal memory would be more optimal[20]. Also, predictions by themselves, however, did not work; feedback seems to be necessary to convert higher self-esteem into altered behaviour[17]. Additionally, research indicates that excessive AI dependency may weaken metacognitive awareness and promote "metacognitive laziness," where AI-generated outputs create illusory competence that discourages reflective monitoring[11][16].

II. F. Cognitive Offloading and AI Dependency:

Effects on Human Cognition and Decision-Making

The ability of our mind to perform mental tasks when using artificial intelligence systems represents an extension of cognitive offloading phenomena[11][12]. Overdependence on AI is the reason for cognitive offloading, whereby individuals hand over their cognitive tasks to AI instead of using their own rationale — a phenomenon which may result in poor internal cognitive functioning. [31]A study examining AI-based tools like ChatGPT found that while AI enhances personalized learning, excessive AI dependence may reduce cognitive engagement and long-term retention. [31]Participants divided into two groups — one that engaged in pretesting before using AI, and a control group that used AI directly — showed that pretesting improved retention and engagement, but prolonged AI exposure led to memory decline.

Risko and Gilbert explained cognitive offloading as the habit of depending on outside tools to make thinking easier. Today, AI takes this even further—not only storing information for us, but also analyzing it and even predicting outcomes, so we end up doing much less thinking on our own[12]. Some research also indicates that relying on AI for cognitive tasks frequently contributes to less mental effort and less engagement of executive

functions[11]. The link between offloading and AI dependency does not follow a straightforward pattern, with moderate AI usage demonstrating minimal cognitive impact while excessive reliance correlates with measurable decreases in unassisted performance outcomes[13]. Gilbert and his team's experiments and investigations reveal that this dependency pattern is particularly seen among the young population aged 17-25, even though people with higher education are generally better at avoiding becoming too dependent on tools like AI[13].

II. G. The Effects of Cognitive Offloading on Critical Thinking: Evidence from AI Usage

The relationship between cognitive offloading and critical thinking is weak in many studies involving quantitative research. However, a structural equation modeling study found that cognitive offloading had important indirect effects on critical thinking with self regulated learning control and cognitive self-efficacy being mediating factors[14]. The partial mediation of critical thinking in the study can be interpreted to mean that offloading does not detract from critical thinking when self-regulation mechanisms are intact and effective[14]. Despite this, critics have raised the concern that AI offloading leads to intellectual laziness as users no longer need to consider effectively how to solve problems[15].

Educational researchers notice that the key concern with task automation through AI-supported offloading lies not in the automating of tasks per se, but rather in AI's interference with cognitive processes of knowledge construction and knowledge verification that reasoning relies on[16]. As Willingham's research shows, however, thought processes are intimately tied to content knowledge: You cannot think critically about something if you know nothing about it[16].

II. H. Artificial Intelligence Dependency and Its Effects on Critical Thinking: Implications for Cognitive Engagement and Decision-Making

Artificial Intelligence (AI) dependency refers to an increasing reliance on AI systems to perform cognitive tasks such as problem-solving, data analysis, and decision-making. Although AI tools enable greater efficiencies, some research argues these tools can harm critical thinking abilities. Research suggests that using AI can reduce the burden of cognitive effort by automating complex processes and reducing opportunities for analytical thought [11][12]. Researchers also found that those who frequently use AI tools show reduced cognitive effort and lower levels of cognitive processes in decision making behaviour [13]. Moderate AI use can aid task completion and learning, though over-reliance may impede independent problem-solving abilities [14].

However, there is some evidence suggesting that over-use of AI could have a negative influence on cognition as it might lead to users escaping cognitive effort [15] and generating the illusion of understanding, such that the over-confident users misjudged their understanding without really increasing the cognitive effort [16] Thus, the effect of the role of AI on critical thinking is mixed, depending on how and how much AI is used.

II. I. Metacognition and Its Effects on Critical Thinking: The Role of Cognitive Awareness and Self-Regulated Learning

Metacognition (thinking about thinking), or awareness of one's own thought processes, is an important component of critical thinking and entails monitoring, evaluating, and regulating one's problem solving activities. Research suggests that the unstructured use of AI leads to a trend of "metacognitive laziness" where the ease of AI-generated content leads to an "illusion of competence" and fails to engage the generative process necessary for the development of profound knowledge construction. People with above-average metacognitive skill may perform better on tasks that are based on analytical reasoning and analytic decision making, due to the online monitoring of thinking processes that these tasks may demand [17].

The structured use of metacognitive prompts, as well as the reflective evaluation of AI-generated content, can lead to better critical thinking. Metacognition may also enable self-regulated learning, eg. recognizing one's knowledge gaps and reasoning

[14]. Metacognition increases critical evaluation of information rather than accepting information passively, especially information from AI technologies [16]. This may reduce the tendency for cognitive biases, and encourage a deeper engagement with the information presented. Metacognition has been shown to improve critical thinking, as monitoring one's own cognitive processes can increase independent evaluation. Elements of reflective thinking, self-awareness, and cognitive control are also relevant in this.

III. RESEARCH METHODOLOGY

This study outlines the comprehensive qualitative approach based on the existing research paper that investigate the relationship between cognitive offloading, AI dependency, critical thinking and metacognition. Furthermore, this research enables researchers to assess how cognitive offloading affects critical thinking with metacognition and AI dependency as a mediating variable and understanding the influence of these variables in decision making.

IV. RESEARCH OBJECTIVES

The objective of this research paper are as follows:

- To explore the relationship between Cognitive offloading and AI dependency.
- To check the relationship between cognitive offloading and metacognition.
- To assess the impact of cognitive offloading on critical thinking directly and indirectly with AI dependency and metacognition as mediator variables.

The overall goal of this qualitative research is to examine the experience and perception of the process of delegating cognitive tasks to AI systems, and how this delegation of tasks affects metacognitive awareness, self-regulated thinking strategies, and critical thinking.

These objectives are based on emerging research that makes a distinction between positive offloading, where AI is used to reduce extraneous cognitive load, and negative offloading, where AI is used to avoid intrinsic cognitive load necessary for deep learning and schema development. This research will also allow researchers to explore rationales for decision-making.The qualitative study can reveal the complex circumstances, situations, and individuals that influence the direction of the user's choice, which cannot be obtained through a quantitative study.

V. RESEARCH GAP

Gerlich (2025) in this paper has investigated the impact of AI tool usage in relation to critical thinking with cognitive offloading as a mediating factor but did not include metacognitive awareness and decision-making variables. Similarly, Guamanga et al. (2025) in this paper focus on the relationship between the variables critical thinking and metacognition, extending it to the context of empathy and psychological well-being. But, the paper has not included the impact of AI dependency and cognitive offloading factors. Furthermore, Ngai and Gilbert (2026) in their paper have analysed how metacognitive awareness influence cognitive offloading. Yet the impact of metacognitive awareness in relation to optimizing cognitive offloading strategies is not included.

However, none of the studies have considered the impact of cognitive offloading, metacognitive awareness, critical thinking, and AI dependency in a unified context with decision-making.

VI. CONCLUSION

The present study aims to investigate the relationship between cognitive offloading, AI dependency, metacognition, and critical thinking in the context of the increasing tendency to employ AI tools. Based on the existing literature, it was revealed that cognitive offloading facilitated by AI tools has both positive and negative impacts on cognitive processes. The current research provides a working model of when cognitive offloading to AI systems may influence critical thinking performance, and the roles that reliance on AI systems and metacognition may play in this process. As AI systems become increasingly integrated into education and the workplace, understanding their impact upon human

cognition is critical. However, findings across this review suggest that while leveraging AI for cognitive offloading can improve efficiency and task performance, reliance on these systems may come at the cost of decreased cognitive effort, self-directed reasoning, and shallow knowledge structures.

Overall, these findings suggest that the relation between dependence on AI and critical thinking is generally not linear or intrinsically negative and often moderated by the level of metacognitive awareness. This indicates that metacognition improves one's ability to regulate AI dependence, critically evaluate AI outputs, and engage in higher-order cognitive processes. In this sense, metacognition can be seen as both a protective factor and a facilitator, thereby changing the role of AI technology from a cognitive proxy to a cognitive coworker.

In summary, this theoretical model provides a first step toward identifying direct and indirect pathways through which cognitive offloading to AI might affect critical thinking. The model can help to guide future critical thinking research on AI and establish that the negative effects of AI on critical thinking are not inevitable. When used appropriately and when metacognitive skills are developed, AI usage could even improve high-order thinking. The study concludes by highlighting the critical need for professional and educational frameworks that support metacognitive training in addition to AI literacy. This strategy will guarantee that human cognition develops in tandem with AI systems, preserving critical thinking, encouraging intellectual independence, and facilitating more productive human-AI cooperation in the digital era.

REFERENCES

1. T. K. F. Chiu and Y. Li, "How can emerging technologies impact STEM education?" Journal for STEM Education Research, vol. 6, no. 1, 2023, doi: 10.1007/s41979-023-00113-w.
2. D. Liu, G. Fan, and L. Pan, "Tool, tutor, or crutch?: A grounded theory of cognitive scaffolding and offloading in AI-assisted programming education," International Journal of STEM Education, vol. 13, art. no. 10, 2026, doi: 10.1186/s40594-025-00592-w.
3. N. Kosmyna et al., "Your brain on ChatGPT: Accumulation of cognitive debt when using an AI assistant for essay-writing task," arXiv preprint, 2025, doi: 10.48550/arXiv.2506.08872.
4. M. U. Pirzado, M. A. Awan, M. Shahzad, et al., "Adoption of AI-coding assistants in programming education: Exploring trust and learning motivation through an extended technology acceptance model," Journal of Computers in Education, 2025, doi: 10.1007/s40692-025-00375-w.
5. S. Sidra et al., "The importance of metacognitive thinking in an artificial intelligence (AI)-enabled workforce," in Proc. IEEE Conf. on Artificial Intelligence (CAI), 2024, doi: 10.1109/CAI59869.2024.00136.
6. J. H. Flavell, "Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry," American Psychologist, vol. 34, no. 10, pp. 906–911, 1979, doi: 10.1037/0003-066X.34.10.906.
7. S. M. Fleming and H. C. Lau, "How to measure metacognition," Frontiers in Human Neuroscience, vol. 8, 2014, doi: 10.3389/fnhum.2014.00443.
8. M. Gerlich, "AI tools in society: Impacts on cognitive offloading and the future of critical thinking," Societies, vol. 15, no. 1, 2025, doi: 10.3390/soc15010006.
9. M. Ataev, "The paradox of cognitive offloading: Assessing the impact of generative AI on critical thinking in higher education," International Journal of Integrated Sciences, vol. 3, no. 3, 2026. [Online]. Available: https://interspp.com/index.php/ijis/article/view/3046
10. E. Ahmedtelba, "Artificial intelligence in higher education: Cognitive offload, patterns, and pitfalls," US-China Education Review A, vol. 15, no. 5, pp. 65–77, 2025, doi: 10.17265/2161-623X/2025.05.001.
11. H. P. Lee et al., "The impact of generative AI on critical thinking: Self-reported reductions in cognitive effort," Microsoft Research, 2025.
12. M. Hümmer, F. Durner, T. Shyiramunda, and M. J. Cummings-Koether, "AI, metacognition, and the

verification bottleneck: A longitudinal study of human problem-solving," arXiv preprint, 2026, doi: 10.48550/arXiv.2601.17055.
13. S. G. B. Johnson et al., "Imagining and building wise machines: The centrality of AI metacognition," Trends in Cognitive Sciences, 2026, doi: 10.1016/j.tics.2026.01.002.
14. Y. Liu et al., "Learners' AI dependence and critical thinking: The psychological mechanism of fatigue and the social buffering role of AI literacy," Acta Psychologica, 2025, doi: 10.1016/j.actpsy.2025.105725.
15. R. Zheng, K. Ning, Q. Zhong, et al., "Towards an understanding of large language models in software-engineering tasks," Empirical Software Engineering, vol. 30, 2025, doi: 10.1007/s10664-024-10466-7.
16. S. Adepoju, "GitHub Copilot's impact on developer productivity: A review of early evidence," International Journal of Scientific Research in Science and Technology, vol. 10, no. 4, pp. 814–822, 2023, doi: 10.32628/IJSRST2221192.
17. L. K. C. Yeung et al., "In ChatGPT they trust: A study of students' perceptions and misuse of ChatGPT in higher education," AI and Ethics, vol. 6, 2026, doi: 10.1007/s43681-025-00855-w.
18. B. Costa-Gomes et al., "It's about time: The Copilot usage report 2025," Microsoft AI, Dec. 2025. [Online]. Available: https://microsoft.ai/news/its-about-time-the-copilot-usage-report-2025/
19. S. Vaughan-Nichols, "GitHub Copilot's effect on collaboration has stunned researchers," The New Stack, Mar. 17, 2026. [Online]. Available: https://thenewstack.io/copilot-reshapes-developer-work/
20. M. Á. Conde et al., "Expanding the lens: Multi-institutional evidence on student use of ChatGPT in higher education," Universal Access in the Information Society, vol. 25, art. no. 48, 2026, doi: 10.1007/s10209-026-01315-w.
21. F. P. V, "Cognitive offloading in the age of artificial intelligence: Psychological implications of excessive AI dependence," IMPACT, vol. 2, no. 1, 2026, doi: 10.61113/impact.v2i1.1266.
22. G. Chirayath, K. Premamalini, and J. Joseph, "Cognitive offloading or cognitive overload? How AI alters the mental architecture of coping," Frontiers in Psychology, vol. 16, 2025, doi: 10.3389/fpsyg.2025.1699320.
23. S. Rao, "The impact of artificial intelligence tools on human cognitive abilities: A comprehensive review," INNOVAPATH, vol. 1, no. 10, 2025, doi: 10.63501/hsdq5611.
24. J. Wang, "Cognitive offloading through digital tools and its relationship with critical thinking, task persistence, and learning depth," Frontiers in Psychology, vol. 17, 2026, doi: 10.3389/fpsyg.2026.1781101.
25. R. Loga, "AI's cognitive implications: The decline of our thinking skills?" IE University, 2025, doi: 10.5281/zenodo.18529064.
26. L. Loble and J. Lodge, "Artificial intelligence, cognitive offloading and implications for education," Australian Network for Quality Digital Education, 2026, doi: 10.71741/4pyxmbnjaq.31302475.
27. Y. Chen et al., "Effects of generative artificial intelligence on cognitive effort and writing performance," Frontiers in Psychology, 2025, doi: 10.1186/s13063-025-08950-3.
28. X. Hu, L. Luo, and S. M. Fleming, "A role for metamemory in cognitive offloading," Cognition, vol. 193, p. 104012, 2019, doi: 10.1016/j.cognition.2019.104012.
29. S. K. Sahakyan and B. J. Delaney, "Can external reminders enhance memory performance?" Memory & Cognition, vol. 47, no. 5, pp. 1009–1020, 2019, doi: 10.3758/s13421-019-00913-7.
30. C. Ngai and S. J. Gilbert, "Metacognitive training facilitates optimal cognitive offloading," Cognitive Research: Principles and Implications, vol. 11, no. 1, p. 21, 2026, doi: 10.1186/s41235-026-00714-0.
31. B. Jose et al., "The cognitive paradox of AI in education: Between enhancement and erosion," Frontiers in Psychology, vol. 16, 2025, doi: 10.3389/fpsyg.2025.1550621.
32. A. Naseer, N. R. Ahmad, and M. A. Chishti, "Psychological impacts of AI dependence: Assessing the cognitive and emotional costs of intelligent systems in daily life," Review of Applied Management and Social Sciences, vol. 8, no. 1, pp. 291–307, 2025, doi: 10.47067/ramss.v8i1.458.

33. S. Bailin and H. Siegel, "Critical thinking," in The Blackwell Guide to the Philosophy of Education, 2003, pp. 181–193, doi: 10.1002/9780470996294.ch16.
34. E. R. Lai, Metacognition: A literature review. Pearson, 2011. [Online]. Available: https://images.pearsonassessments.com/images/tmrs/Metacognition_Literature_Review_Final.pdf
35. P. Dawson, "Cognitive offloading and assessment," in Re-imagining University Assessment in a Digital World, Cham: Springer, 2020, pp. 37–48, doi: 10.1007/978-3-030-41956-1_3.