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The Role of Artificial Intelligence in Enhancing Critical Thinking Skills of Educational Technology Students: The Moderating Influence of Digital Literacy and Usage Regulation

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Abstract

This research examines the role of artificial intelligence (AI) in developing the critical thinking skills of students in the Educational Technology program. In the digital age, critical thinking is essential for objectively evaluating information, solving problems, and making rational decisions. However, much of the learning in higher education is still one-way, limiting the development of these skills. Thru literature review, this study examines the relationship between AI usage and critical thinking skills, specifically in the context of higher education. The results show that AI can trigger students' analysis, evaluation, and reflection processes thru adaptive and interactive learning, with immediate feedback and personalized learning. Nevertheless, the successful implementation of AI depends on students' digital literacy, pedagogical design, and policies regarding AI use on campus. Other challenges such as technology dependence, algorithmic bias, and faculty readiness also need to be considered. A key novelty of this study is the identification of cognitive off-loading as a central risk, highlighting that AI's impact is not merely supportive but can potentially weaken students' independent reasoning if not regulated properly. This novelty underscores the urgent need for clear usage guidelines to ensure that AI strengthens rather than replaces students' critical thinking processes. Overall, this research indicates that integrating AI into learning can enhance students' critical thinking abilities, provided it is used to support independent thinking and reflection, with a planned and ethical approach, making AI an intellectual partner in active, creative, and meaningful learning.

Keywords: Artificial intelligence (AI), critical thinking skills, digital literacy, educational technology

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INTRODUCTION

Technological developments in recent decades have shown significant changes in how the learning process is conducted in higher education institutions. This is evident from the emergence of digitalized learning management system (LMS) usage. And now, the emergence of artificial intelligence (AI)-based applications is further opening up opportunities for personalized learning, dynamic material adaptation, and more advanced learning analytics (Mukti, 2023). The presence of Artificial Intelligence can also make a significant contribution to the development of educational technology, facilitating more effective and personalized learning (Putri et al., 2023). In the context of educational technology, AI can take the form of intelligent tutoring systems, virtual assistants, adaptive quiz platforms, and even the analysis of student learning behavior. Artificial intelligence, or AI, is a field of science that allows computers to learn and think like humans. In education, artificial intelligence, or AI, has seen rapid development and can be used for various purposes (Raharjo, 2023), specifically, this article refers to critical thinking skills among students.

One of the key abilities that is the focus of higher education is critical thinking. According to Davidi, et. Al., (2021) in Mardiyah et al., (2023) critical thinking is explaining how the ability to reanalyze what has been found, re-evaluate, and update existing thinking. Critical thinking also includes the ability to evaluate arguments, solve problems reflectively, connect new information with prior knowledge, and make decisions based on in-depth analysis (Manurung et al., 2023). In the Delphi report, critical thinking consists of six core abilities: interpretation, analysis, evaluation, explanation, inference, and self-regulation. There are also seven dispositions, including truth-seeking, open-mindedness, analytical thinking, systematic thinking, curiosity, prudence, and confidence in reasoning (Zeng & Ravindran, 2025). With this, artificial intelligence or AI can be utilized as a tool that can provide quick and personalized feedback, allowing students to better understand the material and develop critical thinking skills (Harmilawati et al., 2024).

In this study, the definition of Critical Thinking refers consistently to the Delphi Report framework, which conceptualizes CT as a set of cognitive skills interpretation, analysis, evaluation, inference, explanation, and self-regulation a long with dispositions such as truth seeking, open mindedness, systematic thinking, and confidence in reasoning. This unified framework is used throughout the article to ensure conceptual clarity and consistency in evaluating AI's role in strengthening students' CT abilities. While previous literature widely highlights the benefits of AI in education such as personalized learning pathways, rapid feedback, and automated support the connection between these advantages and the actual development of students' critical thinking remains insufficiently integrated within existing discussions. In many studies, AI is treated as a general learning enhancement tool, whereas critical thinking requires deliberate processes of analysis, evaluation, and reflective judgment that do not automatically emerge from AI use. This indicates that AI's pedagogical value is highly dependent on whether its features genuinely stimulate students' cognitive engagement rather than replace it. Therefore, a clearer conceptual linkage between AI integration and the mechanisms of critical thinking is necessary to understand how AI may strengthen or potentially



weaken students' intellectual autonomy. This issue becomes even more urgent in the context of Educational Technology students, who are future designers and implementers of AI-based learning environments. If their use of AI leads to cognitive off-loading rather than deeper reasoning, it may shape not only their personal competencies but also the quality of future educational technologies they create

Entering an increasingly complex and information-filled digital era (including information accessed thru digital technology), students are expected not only to passively receive knowledge, but also to be able to think critically about the content, methods, and implications of the learning materials circulating. However, there are still significant challenges for them to become fully digitally competent learners, such as negative attitudes toward technology-enhanced learning, especially artificial intelligence or AI, and challenges in critical thinking processes due to a lack of understanding of critical thinking abilities (Gao et al., 2025), and the tendency to use technology as a shortcut without deep reflection.

Although there have been a number of studies examining the use of AI in education, for example, as adaptive tutors or interactive media (Xu et al., 2024). Research specifically exploring the impact of AI on students' critical thinking abilities in the field of educational technology is still relatively limited. Some studies show a positive effect of AI use on critical thinking skills, such as helping students access information more widely, accelerating material understanding, and enabling personalized learning according to individual needs (Ma'wa, 2024). However, many also show that the effect is inconsistent or even poses risks such as technology dependence (cognitive off-loading), thus reducing independent thinking (Fauziyati, 2023). As seen in the study in Indonesia, which found that the combined use of AI and digital literacy can influence students' critical thinking abilities in vocational high schools (Nadiyah et al., 2025). However, studies targeting students in educational technology programs, with an analytical framework that includes moderating variables such as digital literacy or usage regulation, are still rare. Additionally, most studies are simple quantitative studies and have not extensively utilized mixed designs or in-depth analysis of the educational technology context.

This research aims to fill the gap by exploring how the use of AI in educational technology can affect students' critical thinking abilities. This particularly critical because Educational Technology students are future designers, developers, and evaluators of AI-based learning systems. If this group experiences cognitive off-loading, the consequences extend beyond personal learning outcomes: it may lead to the creation of AI-dependent learning designs that weaken students' autonomy, reduce pedagogical integrity, and reinforce unhealthy reliance on automated solutions. Therefore, focusing on this population is essential to ensure that future AI-driven educational innovations remain ethical, reflective, and supportive of genuine critical thinking. Specifically, this research aims to describe: (1) the extent to which AI use is related to the critical thinking abilities of educational technology students, (2) other variables that moderate or facilitate this relationship (e.g., digital literacy, usage regulation, pedagogical design), and (3) the challenges and implications of AI implementation for developing critical thinking in higher education.



This research is expected to make a significant contribution to the world of higher education, particularly the educational technology department, in terms of the wise and designed implementation of AI to strengthen students' critical thinking abilities. The results of this study can serve as a reference for lecturers, curriculum developers, and educational institutions in designing AI-based learning interventions that not only simplify the learning process but also explore and strengthen critical thinking skills. Thus, educational technology is not only an efficiency tool, but also a catalyst for developing the thinking competencies needed in the 21st century.

METHODS

This research uses the literature review method with a narrative systematic approach, which was conducted by tracing scientific articles related to the use of AI in higher education and its impact on critical thinking skills. The primary databases used are Google Scholar and Sciencedirect, with a focus on publications from the last few years (approximately 2023-2025) to ensure current relevance. Inclusion criteria include articles that: (1) discuss the use of AI in higher education or technology education, (2) evaluate or discuss critical thinking skills or are related to higher-order thinking, (3) are published in accredited Indonesian journals or relevant international journals. Among the articles found, a number of them are from the Indonesian context, thus considering the local context in the analysis.

The literature selection process included searches using the keywords "artificial intelligence AND critical thinking AND higher education", "AI in education AND higher order thinking", "artificial intelligence AND critical thinking AND college students", as well as publication year filters and relevance to the educational technology context. After screening the titles and abstracts, the full texts were then read for methodological aspects, research variables, results, and implications. The data obtained were then analyzed thematically to identify key patterns, moderating/mediating variables, and practical implications.

RESULTS AND DISCUSSION

Digital Literacy as a Determinant of Meaningful AI Integration in Student Learning

Literature analysis indicates that, in general, the use of AI in learning in higher education has a positive relationship with students' critical thinking abilities. A study evaluating the effectiveness of AI-based learning tools and customized curricula in Indonesia found that AI integration significantly improved students' critical thinking skills. Another study also showed that the simultaneous use of AI and digital literacy influenced the critical thinking abilities of vocational high school students with a high level of significance (Mayasari et al., 2024). However, this influence is often not very large or is limited to student groups with specific conditions (e.g., high digital literacy, good usage regulation) (Nadiyah et al., 2025). For example, in a study of economics and business students in Indonesia, the use of AI had a significant positive impact on critical thinking, but only accounted for 11.2% of the



variance in critical thinking ability (Pasca Arnu & Sobandi, 2025). The study showed that although there were effects, the effect size was relatively small and many other factors were still influential.

Furthermore, the literature indicates that variables such as students' digital literacy, the regulation of AI use (e.g., how instructors guide AI usage), and pedagogical design (whether AI is used solely as an aid or truly integrated into the reflective process) play a significant role as moderators or mediators. For example, a thematic study of critical thinking landscapes in the AI era shows that AI literacy is becoming an important dimension in the development of critical thinking in higher education (Salido et al., 2025). Additionally, there is research indicating that over-reliance or uncontrolled use of AI can have negative consequences, namely a decrease in independent thinking and an increased tendency toward "cognitive off-loading," or shifting the burden of thinking to machines, which results in students processing information less reflectively (Gerlich, 2025). Some studies also highlight that infrastructure challenges, teacher and student literacy, and ethical aspects are obstacles to the effective implementation of AI (Raharjo & Rohmadi, 2025).

Mitigating Cognitive Off-Loading Through Intentional and Reflective Learning Design

In the context of Educational Technology courses, AI tools can also be used intentionally to stimulate reflection rather than automate tasks. For example, students may use ChatGPT or Google Gemini to analyze learning data, review instructional materials, or evaluate digital learning designs. By providing reflective prompts such as "Identify possible pedagogical explanations for this learning pattern" or "Evaluate this AI-generated lesson plan using appropriate learning theories," instructors can ensure that AI encourages deeper reasoning instead of passive acceptance of output.

How AI impacts students' critical thinking

The findings on the use of AI, which can support the enhancement of students' critical thinking abilities in educational technology programs, indicate that the technology is not just a tool for efficiency, but also has deeper pedagogical potential. When AI is used appropriately, for example, as an adaptive learning assistant, a reflective feedback provider, or an interactive medium that encourages students to think and analyze, students can be guided to evaluate arguments, weigh alternatives, and connect different concepts in their learning. This aligns with the literature findings that integrating AI into interactive learning strategies can increase active participation and student reflection (Setiawan & Wibowo, 2025).

However, the finding that the effects are not always large or consistent suggests that AI is not a single solution for improving critical thinking. The decline in independent thinking or the tendency to "rely" on AI without a process of reflection is a side effect that needs to be considered. For example, studies show that using AI is beneficial, but if students lose the habit of independent thinking or instructors provide insufficient guidance, critical thinking skills will be underdeveloped (Arifa Hulmi & Apriadi, 2025). Thus, the implications of using AI in higher education are that the technology needs to be implemented alongside supporting systems such as digital literacy training, pedagogical settings that



encourage reflection, and appropriate faculty scaffolding. Therefore, efficient user engagement with Responsible AI can accelerate ethical acceptance and adoption, highlighting the positive impact on behavioral intentions toward Responsible AI (Chedrawi et al., 2025).

Artificial Intelligence (AI) is transforming higher education, particularly in its ability to foster and enhance critical thinking skills among students. As we move deeper into the digital age, critical thinking has become an essential skill for students, enabling them to objectively evaluate information, solve complex problems, and make rational decisions (Setiawan & Wibowo, 2025). AI, with its diverse and evolving applications, offers numerous ways to engage students in more interactive and dynamic learning processes that significantly contribute to the development of these crucial skills. One of the primary benefits of AI in education is its ability to provide personalized learning experiences. AI-powered systems are capable of adapting learning materials to meet individual students' needs, abilities, and learning preferences. This adaptability ensures that content is delivered at the right level of difficulty, neither too challenging nor too simplistic, which allows students to engage with the material at their own pace. This personalization encourages a deeper connection to the subject matter, pushing students to engage in active learning, ask questions, and critically analyze what they are studying. By promoting self-directed learning, AI helps students move from being passive recipients of information to active participants who evaluate and reflect on the material critically.

In addition to personalized learning, AI also offers immediate feedback, which plays a vital role in enhancing critical thinking. Unlike traditional learning environments, where feedback may be delayed or generalized, AI systems provide instant responses to students' inputs, allowing them to assess their performance immediately. This rapid feedback loop helps students identify mistakes, clarify misunderstandings, and refine their thought processes in real-time (Salido et al., 2025). By addressing errors as they arise, students are encouraged to think critically about their decisions, correct their reasoning, and gain a deeper understanding of the concepts at hand. The immediate nature of AI-driven feedback fosters reflection and promotes continuous improvement in students' thinking.

AI also facilitates immersive learning experiences, such as simulations and problem-based learning (PBL), which are essential for developing critical thinking skills. In PBL, students are presented with real-world problems that require them to analyze situations, evaluate possible solutions, and reflect on the consequences of their decisions. AI can enhance this process by creating adaptive and interactive learning environments where students engage in complex problem-solving tasks (Chedrawi et al., 2025). Through simulations and virtual scenarios, AI helps students explore multifaceted problems that mimic real-world complexities. These experiences encourage students to think critically about the challenges they face, assess different solutions, and make informed decisions based on evidence and reasoning. This form of learning not only enhances their problem-solving skills but also nurtures their ability to critically evaluate outcomes and adjust their strategies accordingly.

Moreover, AI enhances collaboration and peer learning, which are also crucial for the development of critical thinking. AI-powered platforms can connect students with peers, mentors, or



experts, facilitating discussions and collaborative problem-solving. By working together, students are exposed to diverse perspectives, which challenges them to analyze, critique, and synthesize different viewpoints. This collaborative process encourages critical evaluation of ideas, as students must articulate and defend their reasoning while considering alternative arguments (Zhai et al., 2024). AI-driven platforms can also suggest relevant content, resources, or discussions based on students' learning progress, ensuring that students are continuously exposed to new ideas and perspectives, thus deepening their critical thinking skills.

In addition to fostering critical thinking through personalized learning and collaboration, AI also helps students develop data-driven decision-making skills. AI can analyze vast amounts of data, such as student performance metrics or trends in learning progress, to offer insights that help students make informed decisions. For example, AI can highlight areas where a student may need improvement, suggest tailored resources, or provide strategies to enhance their learning (Mayasari et al., 2024).. By incorporating AI-driven data analysis, students learn to assess information critically, weigh evidence, and make decisions grounded in objective analysis. This capability is especially important in today's information-rich world, where the ability to distinguish between reliable and unreliable data is vital for critical thinking. Furthermore, AI encourages independent research, which is central to the development of critical thinking. AI tools, such as virtual research assistants or academic databases, can guide students in navigating vast amounts of information, suggesting relevant research papers, articles, and resources. This helps students engage in deeper inquiry and independent exploration of topics. By facilitating self-directed research, AI empowers students to challenge existing knowledge, ask new questions, and explore alternative viewpoints. This fosters a mindset of inquiry, where students critically assess information, conduct rigorous investigations, and form their conclusions based on evidence rather than accepting information at face value.

Finally, AI can help students recognize and address cognitive biases in their thinking. AI systems can identify patterns in students' reasoning and offer insights into potential biases that may affect their conclusions. For example, AI tools can highlight when a student's argument relies too heavily on a single source of information or when they overlook alternative perspectives. By making students aware of their cognitive biases, AI encourages them to refine their thinking, adopt a more open-minded approach, and critically evaluate the assumptions underlying their reasoning.

In conclusion, AI offers a wealth of opportunities to enhance critical thinking skills in higher education. By providing personalized learning experiences, offering immediate feedback, facilitating immersive problem-based learning, supporting collaboration, enabling data-driven decision-making, and fostering independent research, AI helps students develop the essential skills needed to analyze, evaluate, and make informed decisions in an increasingly complex world. However, the effectiveness of AI in fostering critical thinking depends on thoughtful implementation, including appropriate pedagogical design, a focus on digital literacy, and ethical considerations. When used correctly, AI can



become an invaluable tool in empowering students to think critically, reflect on their learning, and become more independent, informed thinkers.

Theoretical Implications

From the perspective of educational theory and learning technology, these findings support the social constructivist theoretical approach, which views learning as an active process where students construct knowledge thru interaction (with lecturers, peers, and technology). Using AI as a learning "partner" can enrich these interactions. Additionally, metacognition theory is also relevant: students who think critically effectively are those who are aware of their own thinking processes, and AI can help facilitate the development of metacognition thru rapid feedback or visualization of the learning process. However, if AI is only used passively, then the theory of replacement emerges, meaning technology takes over human thinking processes that should be. This challenges the theory that automated technology is always an improvement in learning. The finding that digital literacy and use regulation moderate the effect indicates that media literacy and technology literacy theories need to be strengthened within the higher education framework.

Practical Applications

The results of this study have several practical implications for teaching in higher education, particularly for educational technology programs: (1) Lecturers and curriculum developers need to design learning tasks or activities that utilize AI not as an "instant answer" but as a tool for reflection: for example, students use AI assistants to generate ideas, then they are asked to compare the AI's output with other sources and justify their choices. (2) Institutions need to improve the digital literacy of students and lecturers: training on the critical use of AI, recognizing algorithmic bias, and the ethics of AI use will strengthen the benefits of this technology in terms of critical thinking. (3) Regulations and guidelines for the use of AI in learning need to be developed, such as how lecturers direct the use of AI, when students are allowed to use AI, and how lecturers guide students to maintain independent thinking. (4) AI integration must be accompanied by pedagogical designs that support metacognition and dialog: for example, thru discussion forums, peer review, written reflection after using AI, and activities that require students to evaluate AI output. (5) Infrastructure and technological support need to be adequate; without smooth access or technical support, AI implementation can become an additional burden and hinder the learning process.

Study Limitations

This study has a number of limitations that must be acknowledged. First, because it only uses literature reviews, the author did not collect any new empirical data, so the results depend on the quality and context of the studies that have already been published. Second, most of the literature found comes from the Indonesian or Southeast Asian context, and the use of AI in educational technology study programs has not been extensively detailed, so generalizations to all educational technology study programs in Indonesia or globally must be made with caution. Third, many quantitative studies only



use simple regression designs or limited measurements of critical thinking ability (e.g., only quizzes or short tests), so the effect sizes and context of moderating variables have not been extensively explored in depth. Fourth, this study has not conducted a analysis to examine the development of students' critical thinking skills over time after using AI, so the long-term effects are still unclear.

Future Research Recommendations

For future research, the following recommendations are important to consider: (1) Conducting empirical research (both quantitative and qualitative) on students in educational technology programs who implement AI as an integral part of their curriculum, using a pre-post design with a control group. (2) Investigating moderator/mediator variables in more depth, such as students' AI literacy levels, students' attitudes toward AI, self-regulated learning, and institutional learning culture. (3) Investigating the long-term effects of AI use on critical thinking skills, whether the observed improvements are sustainable or decline over time if AI use is not controlled. (4) Exploring the specific context of educational technology (e.g., Educational Technology programs, Information Systems, Multimedia Education) and comparing across disciplines to see if the effects of AI use differ. (5) Examining the ethical aspects and algorithmic bias in the direct use of AI in learning on the development of critical thinking, whether students are aware of AI output bias and how they respond to it.

CONCLUSIONS

The main conclusion of this study is that the use of AI has the potential to enhance students' critical thinking skills by providing adaptive feedback, supporting analytical processes, and facilitating reflective learning. However, this benefit depends heavily on students' digital literacy, ethical awareness, and the presence of clear campus-level regulations governing AI use. A key novelty of this study is the identification of cognitive off-loading as a central risk, showing that unregulated AI use may weaken students' independent reasoning and long-term cognitive development. For example, a recent study involving 580 Chinese university students found that greater AI dependence was associated with lower critical thinking scores, mediated by cognitive fatigue (Tian & Zhang, 2025). Similarly, a local survey reported that 90.7% of students used AI for academic tasks, indicating widespread adoption and a potential risk of over-reliance (Lukman et al., 2025). In addition, the proposed AI-based learning framework does not merely support students in completing learning tasks more efficiently, but also introduces deliberate cognitive challenges that require them to think independently. By presenting multiple solution paths, alternative interpretations, or conflicting outputs, AI tools can prompt students to justify their reasoning, evaluate the validity of information, and construct evidence-based decisions. This shift ensures that AI becomes a stimulus for higher-order thinking rather than a shortcut that replaces it. These findings reinforce the importance of establishing institutional guidelines and



reflective pedagogical approaches to ensure that AI functions as an intellectual partner that strengthens rather than replaces students' autonomy, reasoning, and meaningful engagement in learning.

Given the complexity of AI integration in Educational Technology programs, future studies should prioritize methodological approaches that allow iterative refinement of AI-based learning interventions. In particular, Action Research and Design-Based Research (DBR) are highly recommended because they enable researchers to test, revise, and optimize AI-supported pedagogical designs directly within authentic learning environments. Unlike simple pre post designs, DBR emphasizes continuous cycles of design, implementation, evaluation, and redesign, making it especially suitable for examining how AI tools can systematically strengthen students' critical thinking skills while mitigating risks such as cognitive off-loading. These approaches would provide richer, contextually grounded evidence to guide sustainable AI adoption in higher education.

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R. D. A.: drafting manuscript, data collection and data analysis.

Y. M. W.: drafting manuscript, translating.

D. A. R. W.: drafting manuscript, finalizing.

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