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Beyond AI adoption: virtual assistants and critical thinking in vocational higher education

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ABSTRACT

Purpose: to examine the effect of AI-based virtual assistant usage on students' critical thinking skills in vocational higher education.
Method: this study employed a quantitative approach using a cross-sectional survey design. Data were collected through an online questionnaire distributed to 131 vocational higher education students who had experience using AI-based virtual assistants in academic activities. The data were analyzed using validity and reliability tests, classical assumption tests, and simple linear regression analysis with SPSS to examine the effect of AI-based virtual assistant usage on students' critical thinking skills.
Findings: the use of AI-based virtual assistants has a positive and significant effect on students' critical thinking skills. The regression analysis shows that AI usage significantly predicts critical thinking ability, and the model demonstrates a moderate explanatory power. Greater engagement with AI-based virtual assistants is associated with higher levels of students' critical thinking skills in vocational higher education.
Implications: AI-based virtual assistants can enhance students' critical thinking skills when appropriately integrated into the learning process.
Originality: focusing on vocational higher education students and empirically examining how the use of AI-based virtual assistants relates to their critical thinking skills in an emerging digital learning context.

Introduction

The development of Artificial Intelligence (AI) technology, particularly through the emergence of large language models (LLMs) and AI-based virtual assistants such as ChatGPT, Gemini, Copilot, and Perplexity, has significantly changed learning practices in higher education institutions across the world (Kasneci et al., 2023; Russell & Norvig, 2020). Students are increasingly utilizing this technology to support various academic activities, from information retrieval and idea generation to assignment completion and

problem-solving. A 2025 report by Public First and Indef indicates that Indonesia is among the countries with the highest levels of generative AI adoption in the world (Indef, 2025). This situation demonstrates that AI has become an integral part of the learning process in higher education, requiring educational institutions to integrate this technology appropriately and responsibly.

This phenomenon is becoming increasingly important in the context of vocational higher education. The Indonesian government has begun integrating AI-based learning into the national curriculum starting in the 2025 academic year, including in vocational education. However, the implementation of this policy still faces various challenges. The digital infrastructure gap persists because not all regions of Indonesia have adequate internet access (Indef, 2025). Furthermore, vocational students are generally more accustomed to using technology as an operational tool rather than utilizing it as a means to develop reflective and analytical thinking skills (Gumartifa et al., 2025). However, vocational education is required to produce graduates not only with technical skills but also with the ability to adapt, critically analyze problems, and make appropriate decisions in the face of technological developments in the workplace (Abbas et al., 2024).

One of the key competencies in the use of AI in educational settings is critical thinking. Critical thinking encompasses the ability to analyze information, evaluate arguments, draw conclusions based on evidence, and reflect on decisions made (Darwin et al., 2024; Essien et al., 2024; Roohr & Burkander, 2020). In the context of AI use, this capability also encompasses students' ability to evaluate the accuracy of AI-generated information, recognize potential algorithmic bias, and determine the relevance of AI responses to the context of the problem at hand (Darwin et al., 2024; Maghfiroh & Widhiastuti, 2025). This competency aligns with the concept of AI literacy proposed by Long & Magerko (2020), which emphasizes the importance of understanding, evaluating, and using AI critically and responsibly. Therefore, critical thinking is a key competency that students must possess so that the use of AI not only improves learning efficiency but also supports deeper thinking processes.

Previous research has shown inconsistent results regarding the relationship between AI use and students' critical thinking skills. Several studies report that the structured use of AI can improve students' critical, reflective, and creative thinking skills (Nasr et al., 2025). Ding et al. (2023) found that AI acting as a virtual tutor encouraged students to ask follow-up questions and explore learning materials in greater depth. Bettayeb et al. (2024) also explained that generative AI can create a more interactive and reflective learning experience when properly integrated into the learning process. Conversely, several studies have shown that excessive use of AI has the potential to reduce the quality of students' thinking processes. Fan et al. (2025) explained that high reliance on AI can lead to the phenomenon of cognitive offloading, namely the tendency for individuals to shift their thinking processes to technology, thereby reducing their ability to reason independently. These findings are supported by Thorndahl & Stentoft (2020), who stated that the use of AI without critical evaluation can reduce student engagement in the analysis and evaluation process. Furthermore, Stadler et al. (2024) showed that although AI is able to reduce cognitive load, this convenience also has the potential to reduce the depth of the scientific thinking process if students rely too much on the answers produced by AI.

The discrepancies in these research findings indicate that the relationship between AI use and critical thinking skills remains an issue requiring further study. In addition to inconsistencies in findings, several research gaps remain. First, most

previous research was conducted in developed countries or in general higher education contexts, while research specifically examining vocational higher education students in Indonesia is still relatively limited (Kudriani et al., 2023). Second, most studies focus on the direct relationship between AI use and learning outcomes without providing an adequate explanation of the psychological mechanisms underlying this relationship (Zhou et al., 2024) Third, there is still little research examining how students' self-regulation skills determine whether AI is used as a tool to deepen learning or replace students' thinking processes (Desai & Chin, 2020). Therefore, the novelty of this study lies in its attempt to examine the effect of AI-based virtual assistant use on the critical thinking skills of vocational students in Indonesia by integrating the perspectives of self-regulated learning and cognitive load theory as a conceptual foundation to explain this relationship.

This study aims to analyze the impact of the use of AI-based virtual assistants on the critical thinking skills of vocational higher education students in Indonesia. This research is important because the implementation of AI in education is developing much faster than the readiness of educational institutions to build a culture of responsible and reflective AI use. Without an understanding of how AI influences students' thinking processes, the integration of this technology has the potential to create cognitive dependency, which contradicts the primary goal of higher education: to produce graduates who are independent, adaptive, and able to think critically in facing various professional challenges. Theoretically, this research is expected to enrich the development of studies on the use of AI in higher education, particularly in the context of vocational education in Indonesia, which has been relatively understudied to date. This research also contributes to the growing literature on the relationship between AI use, critical thinking skills, and self-regulation processes in learning. Practically, the research findings are expected to serve as a basis for higher education institutions, study program managers, and policymakers in designing AI integration strategies that not only improve learning efficiency but also encourage the development of students' critical thinking skills.

This study draws on the self-regulated learning theory proposed by Zimmerman (2002). This theory explains that effective learning occurs through a cycle of planning, monitoring, and self-reflection. In the context of AI-assisted learning, students with good self-regulation tend to use AI strategically, verifying the information obtained and reflecting on their understanding, rather than simply passively accepting AI answers (Wang, 2026). Furthermore, this study also utilizes cognitive load theory, which explains that AI can reduce extrinsic cognitive load so that students' cognitive resources can be diverted to deeper analysis (Sweller et al., 2011). However, if used excessively as a substitute for thinking processes, AI can actually increase cognitive dependency, potentially weakening students' critical thinking skills (Stadler et al., 2024). Based on these two theoretical foundations, the use of AI as a virtual assistant is expected to provide support to the learning process when utilized appropriately. AI can help students obtain initial information, expand knowledge exploration, and facilitate the reflection process, thus potentially improving critical thinking skills. Therefore, this study proposes a hypothesis (H1) that the use of AI-based virtual assistants has a positive and significant effect on the critical thinking skills of vocational higher education students in Indonesia.

Method

This study uses a quantitative approach with an explanatory survey design to

examine the effect of using an Artificial Intelligence (AI)-based virtual assistant on students' critical thinking skills. The quantitative approach was chosen because it allows for objective testing of relationships between variables through statistical analysis. At the same time, the survey design was used to obtain empirical data regarding students' perceptions and experiences of utilizing AI in learning activities. This study is cross-sectional, meaning data collection was conducted over a single period of time through the distribution of online questionnaires to respondents who met the research criteria.

The study population was Indonesian university students who had used AI-based virtual assistants, such as ChatGPT, Gemini, Microsoft Copilot, or Perplexity AI, in their academic activities. Given that the population size could not be precisely identified, this study employed a non-probability sampling technique with the accidental (convenience) sampling method, selecting respondents based on ease of access and their willingness to participate. This technique was deemed appropriate because the study focused on students who already had experience using AI in their learning process. A total of 131 respondents completed the questionnaire and met the criteria for analysis. All respondents stated that they had used at least one type of AI-based virtual assistant in various academic activities, such as searching for information, understanding course material, developing ideas, or assisting with assignment completion.

This study involved two variables: the use of AI-based virtual assistants as the independent variable and students' critical thinking skills as the dependent variable. The AI usage variable was measured through indicators reflecting the frequency of AI use, the intensity of AI utilization in completing academic assignments, and the level of student dependence on AI as a learning aid. Meanwhile, critical thinking skills were measured by adapting the critical thinking dimensions developed by Facione (2011), which include analysis, evaluation, inference, explanation, and self-regulation. These five dimensions were chosen because they represent higher-order thinking skills relevant to the context of AI-assisted learning.

The research instrument was a closed-ended questionnaire constructed using a five-point Likert scale, with a score range of 1 (strongly disagree) to 5 (strongly agree). The questionnaire consisted of 15 items, including 7 items to measure the use of AI-based virtual assistants and 8 items to measure students' critical thinking skills. Before being distributed to respondents, the instrument first underwent an expert judgment process to evaluate the suitability of the indicators to the research construct, the clarity of each statement's wording, and content validity. Subsequently, data collection was conducted online through a digital questionnaire platform, including information regarding the research objectives, the confidentiality of respondent data, and a statement that participation was voluntary.

The quality of the instrument was evaluated through validity and reliability tests. Validity testing was conducted using the Pearson Product-Moment correlation to determine the ability of each statement item to represent the construct being measured. Furthermore, instrument reliability was tested using the Cronbach's Alpha coefficient to ensure the internal consistency of the research instrument. Prior to hypothesis testing, the data were first tested using classical assumption tests, including normality and heteroscedasticity tests, to ensure the regression model met the required statistical assumptions.

Data analysis was conducted in stages, beginning with descriptive statistical analysis to describe the characteristics of respondents and the tendencies of responses to each research variable. Next, instrument quality was tested through validity and reliability tests, followed by classical assumption testing. Simple linear regression

analysis was used to test the research hypothesis because this study only involved one independent variable and one dependent variable. The analysis aimed to determine the magnitude of the effect of using an AI-based virtual assistant on students' critical thinking skills. The entire statistical analysis process was conducted using IBM SPSS Statistics software with a significance level (α) of 0.05.

Results and discussion

Respondent characteristics

Before conducting the inferential analysis, a descriptive analysis was performed to provide an overview of the respondents' characteristics. As presented in Table 1, the respondents were described based on gender, age, year of study, and frequency of AI-based virtual assistant usage in academic activities.

Table 1 respondent characteristics

Characteristic	Category	Frequency	Percentage (%)
Gender	Male	58	44.3%
	Female	73	55.7%
Age	17-19 years	88	67.2%
	20-22 years	35	26.7%
	>22 years	8	6.1%
Year of study	Year 1	79	60.3%
	Year 2	38	29.0%
	Year 3 and above	14	10.7%
Frequency of AI use	Every day	65	49.6%
	Several times a week	47	35.9%
	Once a week	11	8.4%
	Rarely	8	6.1%

Source: primary data, processed (2026)

Table 1 presents the demographic characteristics of the 131 respondents who participated in this study. Based on gender, the majority of respondents were female, accounting for 73 students (55.7%), while 58 respondents (44.3%) were male. This distribution indicates a relatively balanced representation of both genders, although female students were slightly more dominant in the sample. In terms of age, most respondents were between 17 and 19 years old, comprising 88 students (67.2%). Respondents aged 20–22 years accounted for 35 students (26.7%), whereas only 8 respondents (6.1%) were older than 22 years. These findings indicate that the sample was predominantly composed of younger undergraduate students who are generally in the early stages of higher education. Regarding the year of study, the majority of respondents were first-year students, representing 79 students (60.3%) of the total sample. This was followed by second-year students with 38 respondents (29.0%), while only 14 respondents (10.7%) were in their third year or above. The predominance of first-year students suggests that the sample mainly reflects the perspectives of students who are relatively new to university learning and digital learning environments.

With respect to the frequency of AI-based virtual assistant usage, nearly half of the respondents (49.6%) reported using AI tools on a daily basis. In addition, 47 respondents (35.9%) indicated that they used AI several times a week, while 11 respondents (8.4%) reported using AI once a week. Only 8 respondents (6.1%) stated that they rarely used AI-based virtual assistants. These results suggest that AI tools have become an integral part of students' academic activities, with approximately 85.5% of respondents using AI either daily or several times per week. This high level of AI adoption demonstrates that the respondents had sufficient experience with AI-based virtual assistants, making them an appropriate sample for examining the relationship between AI usage and critical thinking skills.

Descriptive statistics

Following the analysis of respondents' characteristics, descriptive statistics were computed to describe the central tendency and distribution of the study variables. As presented in Table 2, the descriptive statistics include the minimum, maximum, and mean scores for AI-based virtual assistant usage and critical thinking skills.

Table 2 descriptive statistics of variables

Variables	N	Min	Max	Mean
AI-based virtual assistants (X)	131	13	35	27.02
Critical thinking skills (Y)	131	14	40	32.54

Source: primary data, processed (2026)

Table 2 presents the descriptive statistics of the two main variables examined in this study, namely AI-based virtual assistant usage and students' critical thinking skills. The descriptive statistics include the minimum, maximum, and mean scores, providing an overview of the respondents' responses to each variable. For the AI-based virtual assistant usage variable, the respondents' scores ranged from a minimum of 13 to a maximum of 35, with a mean score of 27.02. Given that the maximum possible score for this variable was 35, the relatively high mean value indicates that the respondents generally reported frequent and intensive use of AI-based virtual assistants in their academic activities. This finding suggests that AI tools have become widely integrated into students' learning processes, supporting various academic tasks such as information retrieval, idea generation, and assignment completion.

Regarding the critical thinking skills variable, the respondents' scores ranged from 14 to 40, with a mean score of 32.54. Considering that the maximum attainable score was 40, the mean score reflects a relatively high level of self-reported critical thinking skills among the respondents. This result indicates that, on average, students perceived themselves as being capable of analyzing information, evaluating arguments, drawing logical conclusions, explaining their reasoning, and regulating their own thinking processes. The descriptive statistics indicate that both AI-based virtual assistant usage and critical thinking skills were reported at relatively high levels among the respondents. These findings provide an initial indication that the sample possessed substantial experience in using AI-based virtual assistants while also demonstrating relatively strong critical thinking abilities. The descriptive results therefore provide an appropriate basis for subsequent inferential analyses examining the relationship between the two variables.

Validity test

To ensure the quality of the measurement instrument, a validity test was conducted for all items measuring the study variables. Table 3 reports the results of the validity analysis based on the comparison between r-count and r-table values.

Table 3 validity test results

Variables	Item	r-count	r-table	Results
AI-based virtual assistants (X)	X1	0.629	0.171	Valid
	X2	0.670	0.171	Valid
	X3	0.658	0.171	Valid
	X4	0.695	0.171	Valid
	X5	0.530	0.171	Valid
	X6	0.590	0.171	Valid
	X7	0.599	0.171	Valid
Critical thinking skills (Y)	Y1	0.804	0.171	Valid
	Y2	0.859	0.171	Valid
	Y3	0.861	0.171	Valid
	Y4	0.878	0.171	Valid
	Y5	0.858	0.171	Valid
	Y6	0.872	0.171	Valid
	Y7	0.844	0.171	Valid
	Y8	0.824	0.171	Valid

Source: primary data, processed (2026)

Table 3 presents the results of the validity test for all measurement items used in this study, which include items measuring AI-based virtual assistant usage and students' critical thinking skills. The validity of each item was assessed by comparing the calculated correlation coefficient (r-count) with the critical value (r-table) of 0.171. For the AI-based virtual assistant usage variable (X), all seven items (X1–X7) demonstrated r-count values ranging from 0.530 to 0.695, which are higher than the r-table value. Specifically, item X4 showed the highest correlation coefficient (r = 0.695), while item X5 recorded the lowest value (r = 0.530). Although there are variations in the strength of correlation across items, all values exceeded the minimum threshold, indicating that each item reliably measures the intended construct. Therefore, all items in this variable are considered valid.

Similarly, for the critical thinking skills variable (Y), all eight items (Y1–Y8) exhibited relatively high correlation coefficients, ranging from 0.804 to 0.878. Item Y4 showed the highest validity score (r = 0.878), while item Y8 had the lowest (r = 0.824). Despite these slight variations, all items substantially exceeded the r-table value of 0.171, indicating strong item consistency and high construct validity. These results suggest that the items used to measure critical thinking skills are highly appropriate and represent the intended dimensions effectively. The validity test results confirm that all measurement items in this study meet the required validity criteria. Both variables, AI-based virtual assistant usage and critical thinking skills, are supported by valid and

reliable indicators, thereby ensuring the suitability of the instrument for further statistical analysis.

Reliability test

The reliability test results of the research instruments are reported in Table 4. Cronbach's Alpha was employed to evaluate the internal consistency of the items for both study variables.

Table 4 reliability test results

Variables	Cronbach's alpha	Standard	Results
AI-based virtual assistants (X)	0.788	0.600	Reliable
Critical thinking skills (Y)	0.939	0.600	Reliable

Source: Primary data, processed (2026)

Table 4 presents the results of the reliability test for the measurement instruments used in this study, assessed using Cronbach's Alpha coefficient with a minimum acceptable threshold of 0.60. The results indicate that both variables demonstrate satisfactory internal consistency. For the AI-based virtual assistant usage variable (X), the Cronbach's Alpha value is 0.788, which exceeds the recommended threshold of 0.60. This result indicates that the items used to measure AI-based virtual assistant usage have a good level of internal consistency and are reliable for capturing the construct consistently across respondents.

Similarly, the critical thinking skills variable (Y) shows a Cronbach's Alpha value of 0.939, which is substantially higher than the minimum standard. This indicates a very high level of internal consistency among the items measuring critical thinking skills, suggesting that the scale is highly reliable and stable in measuring the intended construct. The reliability analysis confirms that both measurement instruments used in this study are reliable. The AI-based virtual assistant usage scale demonstrates good reliability, while the critical thinking skills scale shows excellent reliability. These results indicate that the instruments are appropriate for further statistical analysis, particularly for hypothesis testing using regression analysis.

Normality test

The normality assumption was tested using the Kolmogorov–Smirnov method, which produced an Asymp. Sig. (2-tailed) value of 0.200. Since this value is greater than the significance level of 0.05, it can be concluded that the residuals are normally distributed. In addition, the heteroscedasticity test based on the scatterplot examination revealed a random distribution of data points without any discernible pattern. This indicates that the variance of residuals is constant across all levels of the independent variable. Therefore, it can be confirmed that the regression model satisfies the classical assumption requirements, including normality and homoscedasticity, and is appropriate for further inferential analysis.

Simple linear regression

The results of the simple linear regression analysis are reported in Table 5. This analysis was conducted to test the hypothesized relationship between AI-based virtual assistant usage and students' critical thinking skills.

Table 5 simple linear regression results

Hypothesis	B	Std. Error	Beta	t-count	Sig.
H1: AI-based virtual assistants (X) → Critical thinking skills (Y)	0.835	0.067	0.738	12.411	0.000
t-table				1.978	
Adjusted r-square					0.541

Source: primary data, processed (2026)

Table 5 presents the results of the simple linear regression analysis examining the effect of AI-based virtual assistant usage on students' critical thinking skills. The findings indicate that AI-based virtual assistant usage has a positive and significant effect on critical thinking skills, as shown by the regression coefficient (B = 0.835) and the significance value (p = 0.000), which is below the 0.05 threshold. The regression coefficient suggests that every one-unit increase in the use of AI-based virtual assistants is associated with an increase of 0.835 units in students' critical thinking skills. In addition, the t-value of 12.411 is substantially higher than the t-table value of 1.978, further confirming that the effect is statistically significant.

The standardized coefficient (Beta = 0.738) indicates a strong positive relationship between AI-based virtual assistant usage and critical thinking skills. This suggests that the use of AI tools plays a substantial role in predicting students' critical thinking performance. Furthermore, the model explains a considerable proportion of variance in the dependent variable, as indicated by the Adjusted R-square value of 0.541. This means that approximately 54.1% of the variation in students' critical thinking skills can be explained by their use of AI-based virtual assistants. In comparison, the remaining 45.9% is influenced by other factors not included in this model. The regression results demonstrate that AI-based virtual assistant usage significantly and positively influences students' critical thinking skills, thereby supporting the proposed hypothesis (H1).

The influence of AI-based virtual assistants on critical thinking skills

The findings indicate that the use of Artificial Intelligence (AI)-based virtual assistants has a positive impact on the critical thinking skills of vocational education students. These findings indicate that the more intensively students utilize AI in academic activities, the better their ability to analyze information, evaluate arguments, draw conclusions, and reflect on their thinking processes. In other words, AI functions not only as a technical tool but also as part of the learning process that can support the development of higher-order thinking skills.

These findings can be explained through the perspective of self-regulated learning (SRL) theory proposed by Zimmerman (2002). In this theory, effective learning occurs when individuals are able to plan, monitor, and reflect on their learning process independently. In the context of AI use, students with strong self-regulation skills tend not to receive information from AI passively but instead use it as material for comparison, analysis, and verification. This process encourages metacognitive activities, which are at the core of critical thinking skills. Furthermore, the cognitive load theory proposed by Sweller et al. (2011) also provides a relevant explanation for these findings. AI plays a role in reducing students' extrinsic cognitive load, particularly in terms of searching for basic information and initial idea formation. With this reduced load, students have greater cognitive capacity to undertake more complex thought processes

such as in-depth analysis, critical evaluation, and decision-making. Therefore, AI in this context can be understood as a tool that enhances cognitive efficiency while supporting the quality of the thinking process.

These findings support previous studies by Essel et al. (2024); Ding et al. (2023), which showed that AI-assisted learning environments can encourage reflective learning and deeper exploration of academic material. These findings align with previous studies showing that integrating AI into learning can positively impact students' critical thinking skills (Habibah et al., 2025; Jia & Tu, 2024; Suriano et al., 2025). Several studies have shown that the targeted use of AI can encourage students to be more active in asking questions, exploring information, and reflecting on learning materials (Aluko et al., 2026; Chang et al., 2023; Yuan & Hu, 2025). AI functioning as a virtual learning partner has also been reported to enhance deeper learning interactions and encourage reflective thinking. Thus, this research reinforces the view that AI can be an effective pedagogical tool when used appropriately in learning contexts.

However, these findings cannot be separated from the context of implementation in the field. In practice, vocational students have now made AI part of their academic routines, whether to search for information, understand material, or assist with completing assignments. This situation indicates that AI has transformed from a mere tool to an integral part of the student learning ecosystem. In such situations, the impact of AI on critical thinking depends heavily on how students use it. When AI is used reflectively, students tend to verify information, compare various sources, and evaluate the answers provided by the AI system. This process indirectly strengthens their critical thinking skills. These findings also highlight the importance of responsible AI use. Excessive reliance on AI can lead to cognitive disengagement and reduce independent reasoning abilities, as suggested in previous studies (Deng & Yu, 2023; Okonkwo & Ibijola, 2021). Therefore, educational institutions should encourage the reflective and purposeful integration of AI to maximize its positive contribution to the development of students' critical thinking.

On the other hand, these findings also provide important indications that the benefits of AI do not occur automatically, but rather are influenced by an individual's ability to manage their learning process. Students with low self-regulation skills are likely to use AI passively, merely as a tool for obtaining instant answers without in-depth analysis. This condition can lead to cognitive dependency, which actually weakens critical thinking skills. Therefore, the presence of AI in learning needs to be balanced with strengthening digital literacy and AI literacy to ensure its use remains productive.

Lecturers have a crucial role in guiding the use of AI through analytical, evaluative, and reflective task-based learning designs. For example, students can be asked to compare AI responses with academic sources, critique AI-generated information, or reflect on their own thinking processes when using the technology. This approach will help ensure that AI is used as a tool for developing thinking, not simply as a tool for completing assignments. Furthermore, from an educational policy perspective, the results of this study demonstrate the need to strengthen curricula that explicitly incorporate aspects of AI literacy and the development of critical thinking skills. This is crucial given that the rapid development of AI technology has not been fully matched by pedagogical readiness in higher education settings, particularly in vocational education. Overall, the findings of this study indicate that the use of AI-based virtual assistants has positive potential in supporting the development of critical thinking skills in vocational students, with the caveat that this impact is highly dependent on how the technology is used in the learning process.

Conclusions

This study shows that the use of Artificial Intelligence (AI)-based virtual assistants has a positive impact on the critical thinking skills of vocational education students. These findings indicate that the more actively students utilize AI in academic activities, the more their abilities to analyze information, evaluate arguments, conclude, and reflect on their thinking processes develop. These results confirm that AI functions not only as a technical tool but also as part of a learning ecosystem that can support the development of higher-order thinking skills when used appropriately and reflectively.

Theoretically, this research contributes to strengthening the application of self-regulated learning theory and cognitive load theory in the context of AI-assisted learning. These findings indicate that the effectiveness of AI use in improving critical thinking skills is greatly influenced by students' ability to regulate their own learning process and the technology's ability to reduce non-essential cognitive load. Practically, the results of this study provide important implications for educational institutions and lecturers to integrate AI into learning in a targeted manner, emphasizing analytical, evaluative, and reflective activities so that the use of AI is not only oriented towards completing assignments but also towards developing students' critical thinking skills.

However, this study has limitations, particularly its cross-sectional design, which prevents it from describing long-term changes in critical thinking skills. Furthermore, the use of convenience sampling also limits the generalizability of the results to a broader population. Therefore, future research is recommended to employ longitudinal or experimental designs to obtain stronger causal evidence. Future research is also recommended to include other variables such as AI literacy, learning motivation, or cognitive engagement as factors that may mediate or moderate the relationship between AI use and students' critical thinking skills.

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