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THE EFFECTS OF ARTIFICIAL INTELLIGENCE, DIGITAL LITERACY, AND CRITICAL THINKING SKILLS ON STUDENTS' MATHEMATICAL PROBLEM-SOLVING ABILITY

Nurul Resky Amelia[1*], Suradi Tahmir[2], Fajar Arwadi[3]
[1,2,3]Departement of Mathematics Education, Universitas Negeri Makassar, South Sulawesi, Indonesia

*Correspondence: nurulreskyamelia.01@gmail.com

ABSTRACT

Previous studies have examined the impact of AI use and students' digital literacy levels. However, they analyzed these variables separately from critical thinking and mathematical problem-solving skills and did not integrate them into a single research model. Therefore, this study integrates these four variables into a single research model to analyze the direct and indirect effects of AI, digital literacy, and critical thinking skills on mathematical problem-solving using a quantitative approach with an explanatory-predictive design in an ex post facto framework. The population in this study consists of all eighth-grade students at public junior high schools in Tamalate Subdistrict, comprising 7 schools with a total population of 1,689 students. The research sample consisted of 11 classes from 4 schools, with a total of 266 students selected through multistage sampling: first, 4 schools were selected using purposive sampling, followed by the selection of classes using proportional cluster random sampling. Data were collected using questionnaires and written tests. All instruments met the criteria for content validity, empirical validity, and reliability. The data were analyzed descriptively and inferentially. Inferential analysis revealed that digital literacy has a direct, positive, and significant effect on critical thinking skills, and that critical thinking skills have a direct, positive, and significant effect on mathematical problem-solving. Conversely, AI has no significant direct or indirect effect on mathematical problem-solving. These findings indicate that critical thinking skills mediate the relationship between digital literacy and students' mathematical problem-solving abilities, while AI serves as a learning tool that requires digital literacy to support it.

Keywords: Artificial Intelligence, Digital Literacy, Critical Thinking Skills, Mathematical Problem-Solving Ability.

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PRELIMINARY

Artificial Intelligence offers many benefits in education, such as virtual assistants, broad access to information, and continuous feedback (Idroes et al., 2023). However, the lack of transfer of learning from the digital environment will make it harder for students to understand problems, construct mathematical models, and solve problems symbolically because learning assessments are conducted on paper and pencil, while the learning process takes place using digital media (Jupri & Drijvers, 2016). Furthermore, the lack of critical evaluation of answers available on digital media, in this case, AI-generated ones, will lead to dependency that can lower academic quality while hindering the development of students' learning skills and critical thinking abilities (Walter, 2024).

Literature reviews by Hadi & Ali (2025) and Zhai et al. (2024) reveal that excessive use of AI can diminish critical thinking skills and creativity in decision-making and pose risks of plagiarism, algorithmic bias, privacy violations, and misinformation. Furthermore, the findings of Schmidt et al., (2025) reveal that the role of AI is viewed from two opposing perspectives: on the one hand, AI is viewed positively because it can help students understand complex concepts, improve academic skills, and support the development of technical competencies such as problem-solving; on the other hand, AI is viewed negatively because excessive use of AI in academic tasks has the potential to reduce students' opportunities to develop and express their creative thinking independently.

Gerlich's (2025) study found that higher trust in AI encourages cognitive offloading, which reduces critical thinking skills. Meanwhile, a study by Bukhari & Akhtar (2025) found that AI use has no significant relationship with problem-solving skills; however, it does have a significant positive relationship with critical thinking skills. When learning is AI-based, two forms of critical thinking emerge: 1) critical thinking based on AI outputs, which encourages students to assess information, compare, consider alternative solutions, evaluate, and refine AI outputs, thereby fostering metacognitive skills; 2) critical thinking in completing tasks using AI, which when used wisely, will foster creative problem-solving in the real world (Gonsalves, 2024). However, Hubaib et al. (2026) found that although students are good at using technology, their digital literacy is only at a moderate level because their ability to evaluate and analyze remains lacking, and their digital activities tend to be for entertainment rather than for learning academic information.

Digital literacy is not merely the ability to use digital media; it also encompasses the ability to find, utilize, process, organize, and evaluate all information obtained from such media, leading to the acquisition of new knowledge that is used effectively and efficiently to disseminate the information in an accurate, wise, and responsible manner (Iryani et al., 2024). Digital literacy helps broaden one's horizons and strengthen critical thinking skills because information is not merely absorbed passively, but involves a process of analysis and evaluation that leads to reflective engagement with content, a process that fosters cognitive competencies that shape critical, analytical, and rational thinking, which is very crucial for navigating modern technology and social complexity (Bakti et al., 2025). This is consistent with the findings of a study by Manggopa & Kumampung (2023), which used the case study method and found that the integration of digital literacy and critical thinking skills fosters creativity in problem-solving, as the information sources available through digital media broaden students' perspectives, enabling them to develop creative, innovative, and effective solutions.

Critical thinking skills contribute to problem-solving because resolving a problem requires elements of critical thinking, including focused, systematic mental activities in decision-making, assumption analysis, and scientific inquiry (Afandi & Ningsih, 2020). Critical thinking plays a vital role in formulating, interpreting, connecting, and developing key ideas from various complex mathematical problems to solve them with minimal errors, thereby ensuring that the resulting decisions are more accurate and effective (Herawati et al., 2025). This is consistent with the findings of Roath et al. (2025), who found that critical thinking skills can explain 30.3% of the variation in problem-solving performance and that a one-unit increase in critical thinking skills raises problem-solving scores by 43.2%, indicating that critical thinking skills play a significant role in improving mathematical problem-solving ability.

Problem-solving skills are an important ability that isn't just limited to learning math but is also relevant to real-life situations and various fields; however, through learning math, students become accustomed to the problem-solving process because they practice understanding issues deeply, analyzing them correctly, choosing effective strategies, doing the necessary calculations, and re-evaluating their solutions (Siswanto & Meiliasari, 2024). However, when solving math problems, students often struggle with function problems, particularly when representing problems as mathematical models and solving them symbolically; these difficulties begin in junior high school and continue through high school (Jupri & Drijvers, 2016). Furthermore, problem-solving ability depends not only on students' mastery of concepts but also on their understanding of the problems they face, enabling them to select appropriate approaches and strategies to solve them (Sulistyani et al., 2020).

Based on these results, it was found that the impact of artificial intelligence use and students' digital literacy levels has been examined in previous studies, with varied results, including findings that are even contradictory. However, these studies analyzed these variables separately from critical thinking and mathematical problem-solving skills and did not integrate them into a single research model, which represents a gap in previous research. Therefore, this study integrates these four variables into a single research model to analyze the direct effects of AI, digital literacy, and critical thinking skills on mathematical problem-solving, as well as the indirect effects mediated by critical thinking skills, so that the results of this study are expected to serve as a reference for enriching research on the integration of AI-based technology and digital literacy into the mathematics learning process, thereby strengthening the theoretical foundation for future research and providing a basis for education practitioners in designing AI- and digital media-based learning to enhance critical thinking skills and mathematical problem-solving abilities.

METHODS

This study employed a quantitative approach with an explanatory-predictive design within an ex post facto research framework. An explanatory-predictive design to analyze the relationships between variables based on naturally occurring conditions, using path analysis as a data analysis technique to examine the direct and indirect effects between variables and to determine the extent to which predictor variables can explain the variation in the predicted variable. The research variables include artificial intelligence (X_1) and digital literacy (X_2) as exogenous variables, critical thinking skills (Z) as an intervening variable, and mathematical problem-solving (Y) as an endogenous variable. Variables Z and Y have residuals (ε) because they are directly influenced by the exogenous variables.

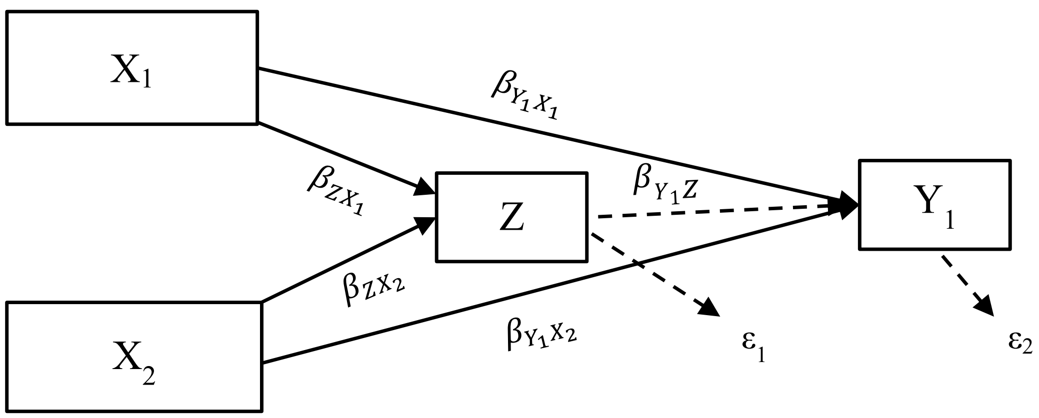

Figure 1. Research Path Analysis Model

Based on the model of relationships among the variables, the following path analysis equations were obtained.

$$Z = \beta_{ZX_1}X_1 + \beta_{ZX_2}X_2 + \varepsilon_1$$

$$Y = \beta_{YX_1}X_1 + \beta_{YX_2}X_2 + \beta_{YZ}Z + \varepsilon_2$$

The study population included all eighth-grade students at public junior high schools in Tamalate Subdistrict, which comprises seven public junior high schools with a total of 1,689 students. Sampling was conducted using multistage sampling. In the first stage, schools were purposively selected based on the criteria that they had covered the topics of relations and functions, were accustomed to using digital media in the learning process, and were willing to serve as research sites; based on these criteria, the selected schools share relatively similar characteristics. Based on these criteria, four junior high schools were selected as research sites, namely SMPN 18 Makassar, SMPN 27 Makassar, SMPN 15 Makassar, and SMPN 55 Makassar. In the second stage, classes were selected proportionally from each school using proportional cluster random sampling, resulting in a research sample of 11 classes from the 4 junior high schools, totaling 266 students.

This study collected data in two ways: through written tests and questionnaires. The written test, in the form of an essay, was used to obtain data on Critical Thinking Skills (CTS) and Mathematical Problem Solving (MPS), while the questionnaire, in the form of a Likert scale, was used to obtain data on Artificial Intelligence (AI) and Digital Literacy (DL).

Table 1. Aspects of AI, DL, CTS, and MPS

No	Aspect AI	Aspect DL	Aspect CTS	Aspect MPS
1	Frequency of AI Use	Digital Information Literacy	Interpretation	Understanding the Problem
2	Purposes and Forms of AI Use	Understanding Digital Information	Analysis	Planning a Solution
3	Integration of AI into Learning	Critical Evaluation of Digital Information	Evaluation	Implementing the Plan
4	AI Support for Conceptual Understanding	Utilization of Digital Information	Inference	Checking the Answer
5	AI Support for Critical Thinking Skills	Digital Ethics and Responsibility		
6	The Impact of AI on Learning Motivation			
7	Personalization of Learning Through AI			
8	AI-Based Social Interaction and Collaboration			
9	Perceptions of AI Reliability and Effectiveness			

The instruments used in AI and DL were developed from aspects devised by the researchers themselves, as available instruments did not fully align with the constructs being measured, the research context, or the students' characteristics. Meanwhile, the CTS instrument is designed based on aspects from Facione's stages, while the MPS instrument is designed based on aspects from Polya's stages.

All instruments have undergone content validity testing, empirical validity testing, and reliability testing. Content validity testing was conducted by two mathematics education experts serving as validators. Based on the qualitative assessment results, both validators stated that the instruments were suitable for use after revision. Suggestions for improvement included refining the grammar to make the instruments easier for students to understand and revising the essay questions to align with the cognitive level of the questions to encourage students to think, thereby allowing assessment of their critical thinking and mathematical problem-solving skills. Meanwhile, the two validators' quantitative assessments on the validation sheets were analyzed using Aiken's V index.

The results of the content validity test on the 30 statement items in the AI and DL instruments, which two experts in mathematics education assessed, showed that all items achieved an Aiken's V score of 1.00. Based on Retnawati's (2020) classification criteria, this value falls into the high category. Thus, all items in the AI and DL instruments meet the content validity criteria.

The results of the content validity test on five essay-type items in the CTS and MPS instruments, which two experts in mathematics education assessed, indicate that, based on Aiken's V categorization criteria according to Retnawati (2020), all items on both instruments exhibited varying levels of content validity. On the MPS instrument, all items received an Aiken's V score of 1.00 and fell into the high category. Meanwhile, in the CTS instrument, item number 1 received an Aiken's V score of 0.67 and fell into the moderate category. In contrast, the other four items received Aiken's V scores ranging from 0.83 to 1.00 and fell into the high category. Thus, all test items in the CTS and MPS instruments met content validity criteria.

In addition, the instruments used in this study were pilot-tested by eighth-grade students at SMPIT Al-Ikhtiar UNHAS who were not part of the research sample. The results of the pilot test were then analyzed using Pearson's product-moment correlation coefficient to assess empirical validity and Cronbach's alpha to assess reliability.

Based on the empirical validity test results for the 30 items in the AI and DL instruments, administered to 45 students, 25 items in the DL instrument met the criteria for empirical validity. In comparison, 5 items did not meet these criteria, specifically items 9, 17, 25, 26, and 27, as they had significance values greater than 0.05. Meanwhile, all items in the AI instrument met the criteria for empirical validity. Therefore, all items in the AI will proceed to the reliability testing phase, whereas for the DL, only the 25 valid items will proceed to the reliability testing phase; the 5 invalid items in the DL will be eliminated from the research instrument.

Based on the results of the empirical validity test of the five essay items on the CTS and MPS instruments, which were administered to 32 students, a significance level of less than 0.05 was obtained for all essay items. Thus, all essay items were deemed valid and will proceed to the reliability testing phase to assess the instruments' level of consistency.

Reliability tests showed that the AI, DL, and CTS instruments had Cronbach's alpha coefficients greater than 0.65. Meanwhile, the MPS instrument had a Cronbach's alpha coefficient between 0.60 and 0.65. The MPS value remains acceptable under Devellis's criteria (Saifuddin, 2020), although it is considered somewhat unsatisfactory. Therefore, all instruments were deemed reliable and suitable for use in collecting data for this study.

Data analysis was conducted using both descriptive and inferential methods with the aid of IBM SPSS Statistics Version 27. However, before the data were analyzed inferentially, prerequisite tests were conducted, including tests for linearity, multicollinearity, and heteroscedasticity, to ensure that the data met the assumptions of parametric statistics. Subsequently, the data were analyzed inferentially to test the direct and indirect effects between variables.

RESULT AND DISCUSSION

Results of Descriptive Statistical Analysis

Table 2. Results of the Descriptive Statistical Analysis

Statistics	AI Statistical Values	DL Statistical Values	CTS Statistical Values	MPS Statistical Values
Sample Size	266	266	266	266
Mean	69.52	73.56	3.68	4.38
Median	70.00	74.00	1.00	3.00
Mode	73.00	75.00	0.00	0.00
Standard Deviation	11.541	11.433	5.729	4.725

Based on Table 2, the mean scores for the AI variable (69.52) fell into the low category, DL (73.56) into the high category, CTS (3.68) into the low category, and MPS (4.38) into the low category. The mode values for AI, DL, CTS, and MPS indicate that the scores most frequently obtained by students on the questionnaire were 73 (AI), which falls in the low category, and 75 (DL), which falls in the high category, while the scores most frequently obtained by students on the essay questions were 0 (CTS and MPS), which fall in the low category. The median values for AI, DL, CTS, and MPS indicate that 50% of students scored above 70 (AI) in the low category, 74 (DL) in the high category, 1 (CTS) in the low category, and 3 (MPS) in the low category. The standard deviation values for AI, DL, CTS, and MPS indicate that AI and DL have relatively small variation around the mean, meaning scores among students tend to be uniform or homogeneous. In contrast, the standard deviation values for CTS and MPS indicate fairly large variations around the mean, meaning scores among students tend to be diverse or heterogeneous.

Table 3. Score Categories for AI and DL

AI Score Range (%)	DL Score Range (%)	Category	AI Percentage (%)	DL Percentage (%)
$97.5 \leq X \leq 120$	$81.25 \leq X \leq 100$	Very High	13	22
$75 \leq X < 97.5$	$62.5 \leq X < 81.25$	High	61	68
$52.5 \leq X < 75$	$43.75 \leq X < 62.5$	Low	24	9
$0 \leq X < 52.5$	$0 \leq X < 43.75$	Very Low	2	1

Based on Table 3, most students' AI usage and utilization levels fell into the high category (61%). Meanwhile, most students' DL levels fell into the high category (68%). This categorization is based on the criteria for converting assessment scores to an ideal benchmark, as outlined by Mardapi, (2020).

Table 4. Score Categories for CTS and MPS

Score Range (%)	Category	CTS Percentage (%)	MPS Percentage (%)
$93 \leq X \leq 100$	Very High	0	0
$84 \leq X \leq 92$	High	0	0
$75 \leq X \leq 83$	Moderate	0	0
$0 \leq X \leq 74$	Low	100	100

Table 4 shows that the CTS and MPS scores for all students fell into the low category (100%). This categorization followed the 2017 assessment guidelines for educators and educational institutions at the junior high school level, while this study set the minimum score threshold at 75, the standard for junior high schools in Tamalate Subdistrict.

The low level of students' CTS proficiency in this study is reflected in their limitations at each CTS stage. At the information-interpretation stage, most students struggled to understand and identify the information provided and the information requested in the questions, even though this is the most basic CTS stage. If students could identify the information, their next weakness lies in the analysis stage, driven by difficulty connecting the problem to the concepts needed to solve it, such as the algebraic operations and manipulations required in CTS, resulting in an inaccurate analysis process. Students' limited conceptual understanding and lack of precision in performing mathematical operations make it difficult for them to evaluate the accuracy of their processes and results. The accumulation of low scores across these four indicators results in students scoring below the minimum threshold of 75.

Meanwhile, students' low MPS scores relate to a lack of practice and familiarity with solving problems step by step, starting at the basic level and progressing to more complex levels. When students face non-routine problems that require higher-order thinking skills, their limited mastery of basic concepts and skills can increase their cognitive load, making it harder for them to understand the problem, choose a strategy, carry out procedures, and check their solutions. Based on the analysis of students' answers, the most common errors in MPS problems occurred during the planning and execution stages of the solution process. This is because students struggled to identify concepts and procedures relevant to the MPS problems; as a result, they often chose inappropriate strategies, leading to incorrect solutions and causing them to score below the minimum threshold of 75.

Results of Inferential Statistical Analysis

Prerequisite Tests

Table 5. Results of the Linearity Test

Variable Relationships	Sig. Deviation from Linearity
CTS * AI	0.961
CTS * DL	0.941
MPS * AI	0.712
MPS * DL	0.746
MPS * CTS	0.084

Based on Table 5, all tested variable pairs had significance values greater than 0.05. This indicates that the relationship between the independent and dependent variables is linear.

Table 6. Results of the Multicollinearity and Heteroscedasticity Tests

Exogenous Variables	Tolerance Value	VIF	Significance
Path Equation I			
AI	0.686	1.458	0.770
DL	0.686	1.458	0.836
Path Equation II			
AI	0.681	1.468	0.954
DL	0.667	1.499	0.270
CTS	0.972	1.028	0.140

Based on Table 6, all exogenous variables in both path equations have Tolerance values greater than 0.10 and VIF values less than 10.00. Therefore, path equations I and II are deemed free of multicollinearity. Furthermore, the significance values in the Park test for all exogenous variables are greater than 0.05, indicating that there is no heteroscedasticity in this research model.

Path Analysis Results

Table 7. Path Coefficient Values

<table>
<tr><th>Exogenous Variables</th><th>Standard Path Coefficient β</th><th>Coefficient of Determination (R^2)</th><th>Residual Coefficient (ε)</th><th>Total Coefficient of Determination</th></tr>
<tr><td colspan="4">Path Equation I</td><td rowspan="7">0.328</td></tr>
<tr><td>AI</td><td>-0.100</td><td rowspan="2">0.028</td><td rowspan="2">0.986</td></tr>
<tr><td>DL</td><td>0.200</td></tr>
<tr><td colspan="4">Path Equation II</td></tr>
<tr><td>AI</td><td>-0.003</td><td rowspan="3">0.309</td><td rowspan="3">0.831</td></tr>
<tr><td>DL</td><td>0.082</td></tr>
<tr><td>CTS</td><td>0.539</td></tr>
</table>

Based on the results of path equation I, the path coefficient of AI on CTS (-0.100) indicates a negative relationship. Meanwhile, the path coefficient of DL on CTS (0.200) indicates a positive relationship.

The results of path equation II show that the path coefficient of AI on MPS (-0.003) indicates a negative relationship. In contrast, the path coefficient of DL on MPS (0.082) indicates a positive relationship. Meanwhile, the path coefficient of CTS on MPS (0.539) indicates a positive relationship. These path coefficient values for models I and II illustrate the magnitude of the direct influence of each variable in the path equations.

Path equation I has an R^2 value of 0.028, which means that 2.8% of the variation in CTS can be explained simultaneously by AI and DL, while the remaining 97.2% of the variation in CTS can be explained by other variables outside this research model. The residual value (ε_1) of 0.986 indicates the magnitude of the influence of external variables not included in path equation I.

Path equation II has an R^2 value of 0.309, meaning that 30.9% of the variation in MPS can be explained simultaneously by AI, DL, and CTS, while the remaining 69.1% of the variation in MPS can be explained by other variables outside this research model. The residual value (ε_2) of 0.831 indicates the magnitude of the influence of external variables not included in path equation II.

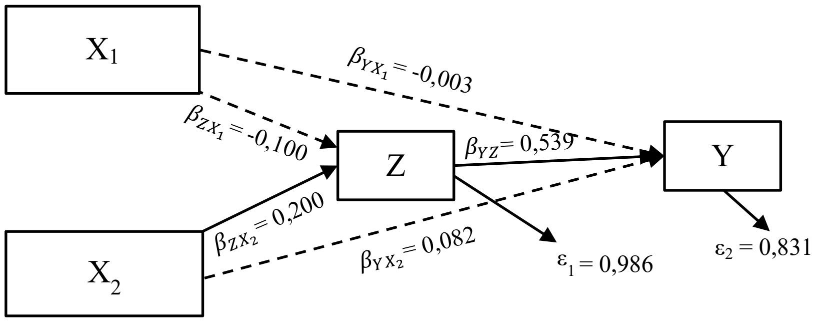

Figure 2. Path Coefficient Diagram in the Study's Path Analysis Model

The total coefficient of determination of 0.328 indicates that collectively, AI, DL, and CTS in the overall path analysis model comprising two path equations can explain 32.8% of the variation in MPS, while the remaining 67.2% of the variation in MPS is explained by other variables not included in this study's model. The path equations for models I and II in this study are as follows.

$$Z = -0{,}100X_1 + 0{,}200X_2 + 0{,}986\varepsilon_1$$

$$Y = -0{,}003X_1 + 0{,}082X_2 + 0{,}539Z + 0{,}831\varepsilon_2$$

Hypothesis Testing

Table 8. Hypothesis Testing for Direct Effects

Hypothesis	Direct Effect	Standardized Path Coefficient β	Partial Test Significance (t)	Decision
H_1	AI → CTS	-0.100	0.175	Not Significant
H_2	DL → CTS	0.200	0.007	Significant
H_3	AI → MPS	-0.003	0.963	Not Significant
H_4	DL → MPS	0.082	0.192	Not Significant
H_5	CTS → MPS	0.539	0.001	Significant

Based on Table 8, it was found that two hypotheses were accepted, namely H_2 and H_5, while the remaining hypotheses, H_1, H_3, and H_4, were rejected. The accepted hypotheses indicate the presence of a significant direct effect between the variables with a significance level of less than 0.05, whereas the rejected hypotheses indicate the absence of a significant direct effect because their significance levels are greater than 0.05.

The accepted hypothesis, namely H_2, has a path coefficient of 0.200, indicating a positive relationship. Thus, every 1-unit increase in digital literacy will increase critical thinking ability by 0.200 units. Meanwhile, H_5 has a path coefficient of 0.539, indicating a positive relationship. Thus, every 1-unit increase in critical thinking ability will increase mathematical problem-solving by 0.539 units.

Table 9. Hypothesis Test for Indirect Effects

Hypothesis	Indirect Effect	Mediation Coefficient Value	Significance (Two-tailed)	Decision
H_6	AI → CTS → MPS	-0.053	0.168	Not Significant
H_7	DL → CTS → MPS	0.107	0.008	Significant

Based on Table 9, hypothesis H_7 was accepted, while H_6 was rejected. The accepted hypothesis indicates the presence of a significant indirect effect between the variables with a significance level of less than 0.05, whereas the rejected hypothesis indicates the absence of a significant indirect effect because its significance level is greater than 0.05.

The accepted hypothesis, H_7, has a mediation coefficient of 0.107, indicating a positive indirect relationship. Thus, the higher a student's level of digital literacy, the higher their critical thinking skills will be, which ultimately leads to an improvement in their mathematical problem-solving abilities.

DISCUSSION

The results of this study indicate that digital literacy has a direct, positive, and significant effect on critical thinking skills, and that critical thinking skills have a direct, positive, and significant effect on mathematical problem-solving. Furthermore, critical thinking skills play a significant role as a mediating variable in bridging the effect of digital literacy on mathematical problem-solving. Conversely, artificial intelligence has neither a significant direct nor an indirect effect on mathematical problem-solving.

The findings of this study are consistent with those of Schmidt et al. (2025), who found that the role of AI is viewed from two opposing perspectives: on the one hand, AI is viewed positively because it can help students understand complex concepts, improve academic skills, and support the development of technical competencies such as problem-solving; on the other hand, AI is viewed negatively because excessive use of AI in academic tasks has the potential to reduce students' opportunities to independently develop and express their creative thinking. In fact, the findings of Bukhari & Akhtar (2025) indicate that the use of AI is not significantly related to problem-solving ability, as demonstrated by a correlation analysis showing no meaningful association between the two variables.

Gonsalves, (2024) also highlights the paradox that AI can foster critical thinking but gradually erode cognitive autonomy if it does not involve in-depth analysis of AI outputs. Furthermore, AI has the potential to reduce students' motivation to conduct independent investigations and evaluations, thereby creating a more passive learning environment (Karimi & Khawaja, 2023). Moreover, Gerlich (2025) results show that greater dependence on AI is more prevalent among younger participants with lower critical thinking scores. However, adolescence is a period characterized by an increased desire to seek thrills or new experiences, the development of executive functions of the prefrontal cortex, which serves as the brain's control center for regulating higher-level cognitive skills consequently, during adolescence, there is an increase in dopamine processing that drives adolescents to explore and gain new experiences (Murty et al., 2016). Therefore, the use of AI among eighth-grade junior high school students is likely still in the exploratory stage, aimed at gaining new experiences and satisfying their curiosity; consequently, its impact on critical thinking and mathematical problem-solving skills has not yet been significantly evident.

Conversely, the results of a study by Aprianto et al. (2025) show that the use of AI has a positive and significant effect on students' critical thinking and problem-solving skills, indicating that the higher the level of AI use in learning, the greater the improvement in students' critical thinking and problem-solving skills. Liu et al. (2026) also found that the use of AI such as ChatGPT in the experimental group had a positive effect on mathematical creativity, self-efficacy, and students' interest in completing assignments because the use of AI in the process of solving math problems gradually internalizes metacognitive skills gained from monitoring, evaluating, and organizing the ideas generated by AI and then transferring them to new situations, which in turn develops the ability to solve math problems creatively.

However, under certain conditions, AI hallucinations can occur, in which the AI generates information that appears valid and convincing even though it is inaccurate, inconsistent, or irrelevant to the information needed; yet the AI presents it in such a convincing manner that students may mistakenly believe it to be true, as it makes it difficult for them to assess the accuracy and validity of the information (Silitonga et al., 2026).

Meanwhile, mathematical understanding is formed when students are able to connect a new concept with at least two previous concepts within their cognitive structure; thus, one of these previous concepts must serve as the parent concept (nearest superordinate) that forms the primary foundation for the new concept, while the other prior concept functions as a supporting element that can be adapted to be transformed into concrete representations or examples (Yang et al., 2021). This becomes a serious problem if AI provides concepts resulting from hallucinations, and students lack strong superordinate concepts to verify their truth when their abilities are low on the relevant material. Students with low ability will have difficulty understanding problems and lack strategies for solving them, and the strategies they choose generally lead to incorrect solutions (Mulbar et al., 2026). Meanwhile, problem-solving is a higher-order thinking activity that uses prior knowledge to find solutions (Andriani, 2016).

Therefore, AI serves not only as a tool for generating information but also shapes the way students interact with knowledge, so that the integration of AI into learning requires an appropriate pedagogical approach and teacher guidance so that students can use the technology critically, reflectively, and in alignment with learning objectives (Pérez-Montesdeoca et al., 2026). When learning involves AI, it can foster critical thinking skills by encouraging students to assess information, compare alternatives, consider alternative solutions, evaluate AI-generated outputs, and refine them, thereby cultivating metacognitive skills and enhancing students' ability to engage in creative problem-solving in real-world contexts (Gonsalves, 2024).

However, current AI applications have not yet made a sufficient contribution to the development of critical thinking skills compared with traditional educational methods that emphasize human interaction and deep reflection (Castillo, 2024). This is because a lack of critical evaluation of AI-generated answers can lead to dependency, which may lower academic quality while hindering the development of students' learning skills and critical thinking abilities (Walter, 2024). Meanwhile, the higher the level of trust in AI, the more it will encourage cognitive offloading, leading to a greater tendency for users to delegate cognitive processes to technology, which is deeply concerning for the development of critical thinking skills, as critical thinking requires active engagement to effectively analyze and evaluate information (Gerlich, 2025).

To develop student thinking processes so that student must be taught the skill of asking questions, as the quality of student dialogue and questions is closely related to student engagement in learning, an important aspect when student interact with AI, this ensures that student are no longer passive recipients of information but active participant in information processing and knowledge construction, which is directly in line with constructivist learning theory, since knowledge is not passively received but is constructed independently by student through active interaction with their learning environment, which in this case is facilitated by AI (Zhao et al., 2026). The information students obtain through digital media is certainly important, but what matters most is learning to think rationally and creatively, because these skills cannot be acquired through digital media (Voskoglou & Buckley, 2012)

However, digital literacy will help students develop critical thinking skills because it involves the repeated evaluation of various pieces of information obtained from digital media, which are then analyzed, compared, and interpreted to uncover the truth, making students accustomed to validating information, verifying data, and being sensitive to information bias (Hubaib et al., 2026). Digital literacy is a skill that extends beyond simply knowing how to use digital media, but also encompasses the ability to find, utilize, process, organize, and evaluate all information obtained from these media, leading to the acquisition of new knowledge that is used effectively and efficiently to disseminate the information in an accurate, wise, and responsible manner (Iryani et al., 2024).

Digital literacy helps broaden one's horizons and strengthen critical thinking skills because information is not merely absorbed passively, but involves a process of analysis and evaluation that leads to reflective engagement with content, a process that fosters cognitive competencies that shape critical, analytical, and rational thinking, which is very crucial for navigating modern technology and social complexity (Bakti et al., 2025). The integration of digital literacy and critical thinking skills fosters creativity in problem-solving, as the information sources available through digital media broaden students' perspectives, enabling them to devise creative, innovative, and effective solutions (Manggopa & Kumampung, 2023). Critical thinking also plays a vital role in formulating, interpreting, connecting, and developing key ideas from various complex mathematical problems to solve them with minimal errors, thereby ensuring that the resulting decisions are more accurate and effective (Herawati et al., 2025).

Critical thinking is the ability to interpret, analyze, evaluate, and draw inferences about a problem through self-explanation and self-regulation in order to reach valid and reliable conclusions (Facione, 1998). Therefore, critical thinking skills contribute to problem-solving because resolving an issue requires elements of critical thinking, including focused, systematic mental activities in decision-making, assumption analysis, and scientific inquiry (Afandi & Ningsih, 2020). In line with research findings Chusniyatin et al. (2026); Handayani (2023); Kaila & Pratama (2025); Puspitasari (2017); Roath et al. (2025), which indicate that critical thinking skills have a positive and significant effect on problem-solving ability, any improvement in critical thinking skills will enhance problem-solving ability. Therefore, these results align with this study's findings, which show that critical thinking skills serve as a mediating variable linking the influence of digital literacy to mathematical problem-solving.

CONCLUSION

Based on the findings of this study, the levels of use and application of artificial intelligence and students' digital literacy are in the high category, while students' critical thinking skills and mathematical problem-solving skills are in the low category. Inferentially, the path analysis results indicate that digital literacy has a direct, positive, and significant effect on critical thinking skills, and that critical thinking skills have a direct, positive, and significant effect on mathematical problem-solving. Conversely, artificial intelligence has no significant direct or indirect effect on mathematical problem-solving. The path analysis also shows that the research model explains 32.8% of the variation in students' mathematical problem-solving, while the remainder is influenced by other variables outside the research model.

The findings of this study are expected to provide empirical information on the importance of digital literacy, so that teachers and schools can design learning experiences that support the development of digital literacy, as improving digital literacy is key to enhancing students' critical thinking skills, while artificial intelligence serves as a learning tool that requires digital literacy skills to support it. Furthermore, for students' understanding of mathematics to develop as they interact with AI, they must possess a superordinate concept that serves as the foundation for learning new concepts through AI. To maintain students' focus on learning through AI, they must be taught the skill of asking questions, as the quality of their dialogue with AI will shape how they interact with knowledge.

This study has several limitations, namely: First, we measured artificial intelligence use and digital literacy using self-report questionnaires. Although the questionnaires capture students' perceptions, experiences, and reported use patterns, self-reported responses may not fully reflect their actual behaviors. In particular, the AI-use measure did not directly capture how students interacted with AI when learning mathematics. The study did not examine the quality of students' interactions with AI, such as the types and quality of prompts used, the extent to which students evaluated AI-generated responses, or how deeply they engaged with AI outputs. Therefore, students who reported frequent AI use may not necessarily have used AI effectively as a learning tool. Second, although essay questions allow students to demonstrate their critical thinking and mathematical problem-solving skills, their answers at each step may be influenced by their habits when working through practice tests, from routine to non-routine problems, as well as their prerequisite mathematical abilities.

For future research, it is recommended to examine the use of AI and digital literacy in greater depth, not only through questionnaires but also through observations of how students use AI and other digital media in the mathematics learning process and in their daily activities, which can be analysed through AI prompts and the history of students' interactions with AI and other digital media. Therefore, it is necessary to develop instruments capable of measuring these aspects.

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