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Integrating Artificial Intelligence into Informatics Education: Effects on Students' Analytical Reasoning and Creativity

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ABSTRACT

The integration of artificial intelligence (AI) in education is rapidly increasing; however, empirical evidence regarding its impact on students' higher-order thinking skills in junior secondary informatics education remains limited, particularly within the Indonesian madrasah context. This study aims to examine the effect of AI integration in informatics learning on students' analytical reasoning and creativity at MTs Negeri 9 Indramayu. A quantitative research design was employed using Partial Least Squares–Structural Equation Modeling (PLS-SEM). The study involved 174 students who had experience using AI-based tools in informatics classes. Data were collected through a four-point Likert-scale questionnaire consisting of 14 items that met established validity and reliability criteria. The results show that AI integration has a positive and significant influence on both analytical reasoning and creativity, with a stronger effect observed on analytical reasoning. The structural model demonstrates moderate explanatory power and satisfactory predictive relevance. These findings contribute to educational technology research by providing empirical evidence that AI can function as a cognitive support system in informatics learning to foster higher-order thinking skills in the madrasah educational environment.

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1. INTRODUCTION

The rapid development of artificial intelligence (AI) in recent years has significantly transformed many sectors, including education. In educational environments, AI technologies such as intelligent tutoring systems, learning analytics, and automated feedback systems enable the development of adaptive and personalized learning experiences that can adjust instructional content, learning pace, and feedback according to students' individual needs [1]. Previous studies have shown that AI-supported learning environments can enhance instructional efficiency and provide data-driven insights for both teachers and students, thereby improving the overall quality of the learning process [2]. As AI technologies continue to evolve, their integration into educational settings has increasingly been viewed as a strategic approach to supporting more effective and responsive learning systems [3].

In the context of informatics education at the junior secondary school level, the integration of AI is particularly relevant because this subject inherently emphasizes the development of higher-order thinking skills [4]. Informatics education not only focuses on mastering technical knowledge and computational concepts but also aims to cultivate students' cognitive abilities, such as analytical reasoning and creativity [5]. Analytical reasoning refers to the ability to systematically analyze problems, evaluate information, and draw logical conclusions based on available evidence [6]. Meanwhile, creativity in learning involves the capacity to generate original ideas, explore multiple problem-solving strategies, and develop innovative solutions when dealing with complex tasks [7]. From a theoretical perspective, AI-based learning technologies may function as a form of cognitive scaffolding, providing adaptive support, immediate feedback, and personalized guidance that can facilitate students' higher-order thinking processes [8].

Despite the promising potential of AI in supporting cognitive development, empirical findings regarding its impact on students' higher-order thinking skills remain inconsistent [9]. Several studies have reported that AI-supported learning environments can significantly improve students' critical thinking, problem-solving abilities, and creativity through personalized learning pathways and adaptive feedback mechanisms [10]. However, other research suggests that excessive reliance on AI tools may reduce students' cognitive engagement and limit the depth of their reasoning processes if the technology is not accompanied by appropriate pedagogical strategies [11]. These contrasting findings indicate that the effectiveness of AI integration in education is not solely determined by technological availability, but also by how the technology is pedagogically designed and implemented in the learning process.

In the Indonesian educational context, particularly at the junior secondary school level, empirical studies examining the relationship between AI integration and students' higher-order cognitive abilities remain relatively limited. Most existing studies primarily focus on teachers' perceptions of AI or the general potential of AI in educational innovation, while quantitative evidence investigating its direct impact on students' analytical reasoning and creativity is still scarce [12]. This research gap becomes even more apparent in informatics education, where the integration of digital technologies often occurs without systematic evaluation of its effects on students' cognitive and creative learning outcomes [13]. Consequently, there is a need for empirical studies that specifically examine how AI integration influences students' analytical reasoning and creativity in real educational settings [14].

This situation is also reflected at MTs Negeri 9 Indramayu, where digital technologies have begun to be incorporated into informatics learning activities. However, the integration of AI within the instructional process remains at an early stage and has not yet been empirically evaluated in relation to its potential impact on students' analytical reasoning and creativity. Considering the rapid global expansion of AI-based educational technologies and the increasing emphasis on developing 21st-century skills, the absence of empirical evidence regarding the effectiveness of AI integration may lead to the adoption of technology without sufficient pedagogical foundations [15].

Therefore, this study aims to analyze the impact of artificial intelligence integration in informatics learning on students' analytical reasoning and creativity at the junior secondary level. By employing a quantitative approach and Partial Least Squares–Structural Equation Modeling (PLS-SEM), this study seeks to provide empirical evidence regarding the role of AI in supporting students' higher-order thinking skills. The findings of this study are expected to contribute to the growing body of research on AI in education while also offering practical insights for teachers and policymakers in designing AI-supported informatics learning environments that promote both analytical reasoning and creativity among students.

2. METHOD

2.1. Research Design

This research utilized a quantitative methodology through a survey technique to investigate how the incorporation of artificial intelligence in informatics education influences students' analytical thinking and creative abilities. The information was evaluated by means of Partial Least Squares Structural Equation Modeling (PLS-SEM), a method commonly utilized to explore the connections among hidden variables, making it appropriate for both predictive and exploratory frameworks within educational studies.

2.2. Participants and Data Collection

The study involved a group of 174 students from MTs Negeri 9 Indramayu who had gone through educational activities in informatics that included the use of artificial intelligence tools. Participants were chosen using a saturated sampling method, which meant all students who qualified based on the research criteria were included in the study.

Information was gathered by using a structured questionnaire that was administered to students following the completion of the learning activities. Prior to filling out the questionnaire, the participants were given an explanation regarding the study's objectives and were assured that their answers would be kept private and utilized solely for academic purposes.

This study also considered ethical aspects. Approval to carry out the research was secured from the school authorities, and students were free to choose whether or not to participate. After giving their informed consent, the students completed the questionnaire, and all information was collected in a way that ensured the anonymity of the respondents.

2.3. Instrument Development

The research tool included a survey consisting of 14 questions aimed at evaluating three primary concepts: the role of artificial intelligence in education, analytical reasoning abilities, and creativity among students. To create the survey questions, a review of existing literature concerning artificial intelligence applications in educational settings,

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analytical reasoning skills, and student creativity in learning environments enhanced by technology was performed.

Some questions in the survey were revised and adapted from earlier research focused on technology-enhanced learning, analytical reasoning, and creative processes in educational contexts. These questions were tailored to align with the context of utilizing artificial intelligence within informatics education at the junior secondary school stage.

All questions were rated using a four-point Likert scale, with options ranging from strongly disagree (1) to strongly agree (4). The intention behind the four-point scale was to motivate participants to provide a definitive level of agreement without the option of a neutral response.

2.4. Data Analysis

The gathered information was examined employing Partial Least Squares Structural Equation Modeling (PLS-SEM). This examination consisted of two primary phases: first, assessing the measurement model (outer model) to determine the reliability and validity of the constructs, and second, evaluating the structural model (inner model) to investigate the connections among artificial intelligence, analytical reasoning, and student creativity.

3. RESULTS AND DISCUSSION

Structural model analysis was conducted using the Partial Least Squares–Structural Equation Modeling (PLS-SEM) method to examine the relationships among artificial intelligence integration (X1), analytical reasoning (Y1), and student creativity (Y2). Based on the estimation results, the use of AI has a positive and significant impact on enhancing students' analytical reasoning and creativity. Furthermore, the model also indicates the extent to which each indicator contributes to the measured constructs, thereby providing a clear overview of the strength of both the measurement model and the structural model.

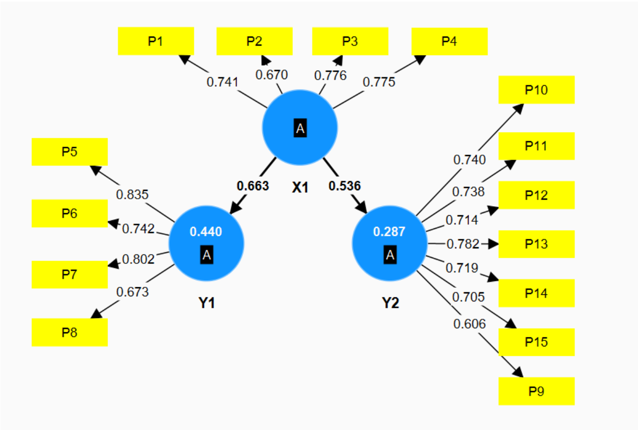

Figure 1. Structural Model of AI Integration on Analytical Reasoning and Student Creativity

Based on Figure 1, the path coefficient from AI integration (X1) to analytical reasoning (Y1) is 0.663, indicating a strong and positive effect. Meanwhile, the impact of AI integration on student creativity (Y2) reaches 0.536, demonstrating a positive and significant relationship, although the strength of this relationship is lower compared to its effect on analytical reasoning. The R-square value of 0.440 for the analytical reasoning variable indicates that 44% of the variance in analytical reasoning ability is explained by the use of AI. In contrast, for the student creativity variable, the R-square value of 0.287 suggests that 28.7% of the variance in student creativity is influenced by AI integration.

From a measurement point of view, all the indicators have loading values that are higher than the minimum required 0.60, which shows that each indicator properly represents its corresponding construct. So, the model is both statistically sound and dependable, and it shows that using AI has a bigger effect on improving analytical thinking skills than on boosting student creativity.

3.1. Measurement Model Evaluation (Outer Model)

This section explains the validity and reliability of the constructs based on the outer model testing results, which include several subsections:

3.1.1. Outer Loadings

Table 1. Outer Loading

	X1	Y1	Y2
P1	0.741		
P10			0.740
P11			0.738
P12			0.714
P13			0.782
P14			0.719
P15			0.705
P2	0.670		
P3	0.776		
P4	0.775		
P5		0.835	
P6		0.742	
P7		0.802	
P8		0.673	
P9			0,606

The outer loading evaluation results indicate that the majority of indicators across the constructs of Artificial Intelligence (X1), Analytical Reasoning (Y1), and Creativity (Y2) have loading values ≥ 0.70, suggesting that these indicators adequately represent their respective latent constructs and meet the criteria for convergent validity. Within the X1 construct, indicators P1, P3, and P4 demonstrate strong contributions, while P2 (0.670) falls slightly below the ideal threshold but can still be retained, as it approaches the cut-off value and does not substantially reduce the overall construct quality.

The Y1 construct exhibits good measurement performance, with the highest loading values observed for P5 (0.835) and P7 (0.802). One indicator, P8 (0.673), shows a marginal value but remains acceptable based on theoretical considerations.

For the Y2 construct, most indicators (P10–P15) display stable loading values above 0.70. However, indicator P9 (0.606) presents the lowest loading and requires careful evaluation. This indicator may still be retained provided that the construct's AVE and Composite Reliability meet the required thresholds and that the indicator has strong conceptual justification.

Overall, the outer loading results demonstrate that the measurement model satisfies convergent validity and is appropriate for proceeding to structural model evaluation.

3.1.2. Average Variance Extracted

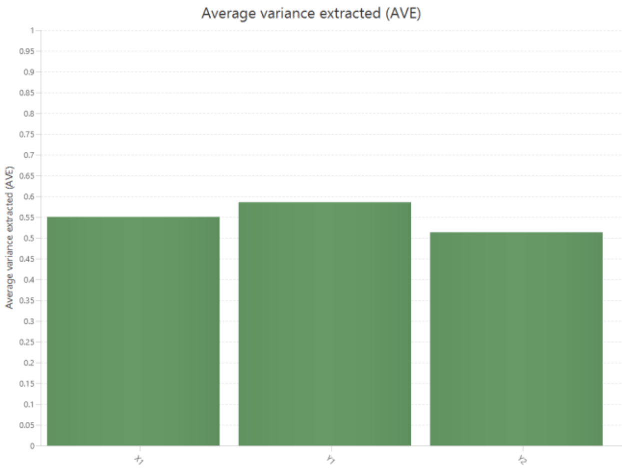

Figure 2. Average Variance Extracted

The Average Variance Extracted (AVE) results indicate that all research constructs, Artificial Intelligence (X1), Analytical Reasoning (Y1), and Creativity (Y2), have AVE values above the minimum threshold of 0.50. The highest AVE value is observed in the Analytical Reasoning (Y1) construct, indicating that this variable explains the largest proportion of variance in its indicators compared to the other constructs.

The Artificial Intelligence (X1) and Creativity (Y2) constructs also demonstrate adequate AVE values, suggesting that more than half of the variance in their respective indicators is explained by the underlying latent constructs. This finding confirms that the indicators exhibit strong consistency and representativeness in measuring the intended constructs.

Overall, the AVE results affirm that the measurement model satisfies the criteria for convergent validity, meaning that each construct sufficiently explains its indicators and is appropriate for further evaluation within the structural model.

3.1.3. Composite Reliability and Cronbach's Alpha

Table 2. Composite Reliability and Cronbach's Alpha

	Cronbach's Alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average Variance Extracted
X1	0.728	0,736	0.830	0.551
Y1	0.763	0.781	0.849	0.586
Y2	0.841	0.845	0.880	0.514

The results from the reliability testing show that all the research constructs—Artificial Intelligence (X1), Analytical Reasoning (Y1), and Creativity (Y2)—have Cronbach's Alpha and Composite Reliability scores that are higher than the minimum required threshold of 0.70, which means they have strong internal consistency. The Cronbach's Alpha scores of 0.728 for X1, 0.763 for Y1, and 0.841 for Y2 show that the indicators in each group are consistently measuring the same main idea.

Also, the Composite Reliability (rho_c) values for all the groups are between 0.830 and 0.880, which means the constructs are reliable and stable in the PLS-SEM model. The rho_a values, which also go above the 0.70 limit, further support the idea that the measurement model is reliable.

Overall, these results show that the research tool meets the reliability standards, meaning the indicators can be trusted to measure the underlying concepts and are suitable for use in structural model analysis.

3.1.4. Discriminant Validity

Table 3. Discriminant Validity

	X1	Y1	Y2
X1			
Y1	0.878		
Y2	0.665	0.802	

The discriminant validity testing results indicate that the correlations among the constructs of Artificial Intelligence (X1), Analytical Reasoning (Y1), and Creativity (Y2) remain within acceptable limits. The correlation values of 0.878 between X1 and Y1, 0.665 between X1 and Y2, and 0.802 between Y1 and Y2 demonstrate that although the variables are related, they still reflect conceptual distinctions among the constructs.

Based on the Fornell–Larcker criterion, the square root of the AVE for each construct is higher than its correlations with other constructs, indicating that each latent variable explains its own indicators more strongly than it explains other constructs within the model. This confirms that discriminant validity has been established at the construct level. The following section presents the Heterotrait–Monotrait Ratio (HTMT) results.

Table 4. Heterotrait-monotrait ratio

Y1 <-> X1	0.878
Y2 <-> X1	0.665
Y2 <-> Y1	0.802

Discriminant validity was further confirmed through the Heterotrait–Monotrait Ratio (HTMT) assessment. The HTMT values were 0.878 for X1–Y1, 0.665 for X1–Y2, and 0.802 for Y1–Y2, all of which fall below the 0.90 threshold. These results indicate that there is no significant measurement overlap among the latent constructs. Even though the highest HTMT value was found between Artificial Intelligence and Analytical Reasoning, it is still within the acceptable range and makes sense according to the theory that sees artificial intelligence as a tool to help students with their learning.

Therefore, the results of both the Fornell–Larcker criterion and the HTMT analysis consistently demonstrate that the model satisfies discriminant validity. All constructs in this study are empirically distinct and appropriate for structural model analysis.

3.2. Structural Model Evaluation (Inner Model)

After the measurement model (outer model) was confirmed to be valid, the next stage involved analyzing the relationships among the latent variables:

3.2.1. R-Square

Table 5. R-Square

	R-square	R-square adjusted
Y1	0.440	0.437
Y2	0.287	0.283

The R-square (R^2) results indicate that the Analytical Reasoning construct (Y1) has an R^2 value of 0.440, with an adjusted R^2 of 0.437. This finding suggests that the exogenous variable, Artificial Intelligence integration in informatics learning (X1), explains 44.0% of the variance in students' analytical reasoning ability. Based on PLS-SEM evaluation criteria, this value falls within the moderate category, indicating that the structural model demonstrates adequate explanatory power for the development of students' analytical cognitive skills.

Meanwhile, the Student Creativity construct (Y2) shows an R^2 value of 0.287 and an adjusted R^2 of 0.283, meaning that 28.7% of the variance in student creativity is explained by the use of artificial intelligence in informatics learning. This value is categorized as weak to moderate, indicating that although AI has a significant effect on creativity, other factors outside the model also contribute to shaping students' creativity, such as pedagogical strategies, learning environment, and individual characteristics.

The difference in R-square values between Y1 and Y2 indicates that artificial intelligence is more effective in supporting analytical reasoning than creativity. This is theoretically plausible, as AI-based technologies tend to be stronger in facilitating logical processing, structured problem-solving, and information analysis compared to divergent and exploratory aspects associated with creativity.

3.2.2. F-Square

Table 6. F-Square

	X1	Y1	Y2
X1		0.785	0.403
Y1			
Y2			

Based on the f^2 value of 0.785 for the path X1 → Analytical Reasoning (Y1), the effect size is categorized as very large. Referring to Cohen's criteria (0.02 = small; 0.15 = medium; 0.35 = large), this value substantially exceeds the threshold for a large effect.

This finding indicates that the presence of the artificial intelligence variable makes a substantial and dominant contribution to explaining the variance in students' analytical reasoning abilities within informatics learning.

Meanwhile, the f^2 value for X1 → Student Creativity (Y2) is 0.403, which also falls within the large effect category. This suggests that artificial intelligence exerts a strong influence on student creativity, although the magnitude of its effect is lower than that observed for analytical reasoning. This difference reinforces the previous R-square findings, indicating that artificial intelligence is more effective in supporting analytical cognitive abilities than creative aspects, which tend to be more complex and context-dependent.

Overall, the f-square results confirm that the artificial intelligence variable is not only statistically significant but also practically meaningful, and therefore warrants retention as a primary variable in the research model.

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3.2.3. Predictive Relevance

Table 7. Predictive Relevance

	SSO	SSE	Q^2 (=1-SSE/SSO)
X1	696.000	696.000	0.000
Y1	696.000	526.073	0.244
Y2	1.218.000	1.052.237	0,136

56 12

The predictive relevance test (Q^2) was conducted using the blindfolding procedure to assess the extent to which the model demonstrates predictive capability for the endogenous constructs. Methodologically, a Q^2 value greater than 0 indicates that the model has predictive relevance, whereas a Q^2 value less than or equal to 0 indicates the absence of predictive capability.

Based on the results, the X1 construct produced a Q^2 value of 0.000. This finding is methodologically acceptable because Q^2 is not evaluated for exogenous constructs, as other constructs in the model do not predict these variables. Therefore, this value is not interpreted and does not indicate a weakness in the model.

For the endogenous construct Y1 (Analytical Reasoning), the Q^2 value obtained was 0.244, indicating moderate predictive relevance. This means that the model has a reasonably strong ability to predict variations in students' analytical reasoning based on the artificial intelligence variable.

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Meanwhile, the Y2 construct (Student Creativity) yielded a Q^2 value of 0.136, suggesting small to moderate predictive relevance. This indicates that although the model retains adequate predictive capability, student creativity is also influenced by other factors outside the model that were not incorporated in this study.

Overall, the Q^2 results confirm that the research model possesses valid and meaningful predictive power, with stronger predictive performance for analytical reasoning compared to student creativity.

3.2.4. Collinearity Statistics

Table 8. Collinearity Statistics

	VIF
P1	1.347
P10	1.936
P11	1.899
P12	1.593
P13	1.783
P14	1.825
P15	1.709
P2	1.282
P3	1.498
P4	1.415
P5	1.659
P6	1.490
P7	1.634
P8	1.324
P9	1.283

The collinearity test results indicate that all indicators have VIF values ranging from 1.282 to 1.936. The highest value was observed for indicator P10 (VIF = 1.936), while the lowest was found for P2 (VIF = 1.282). All values are well below both the conservative threshold (VIF < 3) and the commonly accepted threshold (VIF < 5).

These findings suggest that each indicator provides unique information, without excessive overlap or high redundant correlations among indicators within the same construct. Consequently, the parameter estimates in the model can be considered stable, reliable, and free from multicollinearity bias.

Overall, the collinearity statistics confirm that the measurement model satisfies the assumption of no multicollinearity. Therefore, all indicators are appropriate for retention, and the model is ready to proceed to structural and hypothesis testing.

3.2.5. Hypothesis Testing

Table 9. Hypothesis Testing

	Original Sample (O)	Sample Mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
X1 -> Y1	0.663	0.669	0.049	13.467	0.000
X1 -> Y2	0.536	0.548	0.064	8.420	0.000

The hypothesis testing results based on the bootstrapping procedure indicate that variable X1 has a positive and significant effect on both Y1 and Y2. The path from X1 to Y1 produced a coefficient of 0.663, with a t-statistic of 13.467 and a p-value of 0.000. The t-statistic substantially exceeds the critical value of 1.96, and the p-value is below 0.05, confirming that the effect is statistically significant. This finding indicates that an increase in X1 is consistently associated with a meaningful increase in Y1; therefore, the hypothesis stating that X1 influences Y1 is accepted.

Furthermore, the path from X1 to Y2 yielded a coefficient of 0.536, with a t-statistic of 8.420 and a p-value of 0.000. These results confirm that the effect of X1 on Y2 is also positive and statistically significant. Although the strength of this effect is lower than its influence on Y1, the relatively large coefficient and high level of significance indicate that X1 plays an important role in explaining the variance in Y2. Accordingly, the hypothesis stating that X1 influences Y2 is accepted, and overall, the hypothesis testing results support the proposed structural model in this study.

3.3. Main Findings

The findings of this study indicate that the implementation of artificial intelligence in informatics learning at MTs Negeri 9 Indramayu has a significant impact on improving students' analytical reasoning and creativity. The primary result demonstrates that artificial intelligence exerts a stronger influence on analytical reasoning than on creativity, suggesting that AI is more effective in supporting structured cognitive processes such as problem analysis, information evaluation, and rational decision-making.

Furthermore, the structural model evaluation reveals that the contribution of artificial intelligence to enhancing student creativity remains significant, although the magnitude of its effect is lower. This suggests that student creativity is influenced not only by AI utilization but also by pedagogical components and the broader learning context [16]. In other words, AI functions as a tool that expands the potential for idea development, yet it does not fully operate as the central driver in the formation of student creativity [17].

Overall, the results indicate that the application of artificial intelligence in informatics learning within the madrasah environment holds substantial potential to improve educational quality by strengthening students' higher-order thinking skills. The tested model meets the standards of validity, reliability, and structural adequacy, thereby providing robust empirical evidence that systematically planned AI implementation can serve as an effective and appropriate instructional strategy at the junior secondary level.

The study further shows that artificial intelligence has a substantial impact on students' analytical reasoning, with a path coefficient (β) of 0.663, consistent with international research conducted within the past five years. Research by [18], later expanded through subsequent systematic reviews, indicates that AI operates as a cognitive support system through adaptive feedback and learning analytics, thereby enhancing analytical thinking and structured problem-solving skills. More recently, research by [19] within the context of STEM education in China demonstrates that adaptive AI-based learning significantly improves students' reasoning abilities through personalized learning pathways and real-time error analysis. These findings suggest that the strong effect of AI on analytical reasoning is not context-specific but observable across diverse educational settings globally [20].

Meanwhile, the effect of AI on student creativity ($\beta = 0.536$), categorized as moderate, is also consistent with international findings. Studies by [21] and [22] report that AI, particularly generative AI, functions as a creativity support tool that facilitates idea expansion and exploration. However, its effectiveness depends heavily on instructional design and teacher guidance. A study conducted in the United States by [23] shows that AI can enhance creative thinking and idea development; nevertheless, without reflective teacher facilitation, such improvements often remain superficial. These findings align with the results observed in Indramayu, where AI's influence on creativity is evident but not as strong as its effect on analytical reasoning, indicating that AI is more effective in reinforcing logical thinking patterns than in deeply cultivating original idea generation.

Therefore, the findings of this study do not stand in isolation but rather reinforce a broader global pattern: artificial intelligence is more consistently effective as a tool for strengthening analytical reasoning than as a primary driver of high-level creativity, unless it is supported by reflective and constructivist instructional design.

3.4. Discussion

From a conceptual standpoint, the outcomes of this research add to the educational technology framework by emphasizing the function of artificial intelligence as a cognitive support system that aids advanced thinking activities in educational settings [24]. The findings reveal that the incorporation of AI in informatics education can improve students' critical reasoning and imaginative skills by offering customized feedback, organized guidance, and individualized learning paths that encourage a more profound involvement with problem-solving endeavors [25]. The more significant impact of AI on critical reasoning rather than on creativity indicates that AI-enhanced educational environments are particularly successful in promoting organized cognitive activities such as assessment, pattern identification, and logical analysis, which are essential in computational and informatics learning [14]. This observation corresponds with the wider theoretical viewpoint that AI should serve as a tool that enhances human cognitive abilities instead of replacing them within the education sector. Besides its theoretical contributions, the results also provide actionable insights for educators and curriculum developers. For educators, the findings emphasize the necessity of incorporating AI tools into instructional methods that are pedagogically relevant, fostering students' abilities to analyze, assess, and thoughtfully engage with outputs generated by AI. This strategy guarantees that AI serves as a support mechanism for cognitive processes rather than simply providing automated responses [26]. For those involved in curriculum development, the insights indicate that the integration of AI should be methodically included within computer science programs that prioritize advanced thinking abilities, analytical problem-solving, and creative investigation. By connecting AI-enhanced educational tools with effective pedagogical frameworks, schools and universities can maximize the capabilities of AI technologies to aid in nurturing students' analytical skills and creativity in modern digital learning settings.

4. CONCLUSION

This research emphasizes the significant impact of incorporating artificial intelligence in enhancing students' higher-order thinking abilities in informatics education. The results demonstrate that environments supported by AI can effectively foster the growth of students' analytical reasoning and creativity, with a more pronounced effect noted in analytical reasoning, stemming from the structured and problem-focused approach of AI-assisted learning. These findings imply that artificial intelligence can serve as a valuable cognitive aid when combined with suitable teaching methods. From a practical standpoint, the results suggest that educators and curriculum developers should use AI-driven learning tools in ways that promote analytical thinking, reflective problem-solving, and creative inquiry, instead of merely relying on AI for automatic responses. Nonetheless, this study has various limitations that need to be recognized. The research took place in a single educational institution, which might restrict the applicability of the findings to wider educational situations. Moreover, the research depended on data gathered through self-report questionnaires, which could indicate how participants view their learning instead of depicting their actual behaviors in learning. Therefore, it is advisable for future studies to utilize experimental methods to investigate the causal effects of learning supported by AI, perform comparative analyses among various schools or educational bodies, and utilize qualitative methods to gain deeper insights into students' thought processes and learning encounters with AI technologies. Despite these constraints, this research adds to the expanding literature on artificial intelligence in the education sector by offering empirical data from the madrasah setting and demonstrating the potential of AI-enhanced learning to improve analytical thinking and creativity in modern digital education.

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