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INTEGRATION OF LOCAL ETHNOMATHEMATICS BASED ON ARTIFICIAL INTELLIGENCE (AI) IN ENHANCING STUDENTS' CRITICAL THINKING SKILLS

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ABSTRACT
This study aims to examine the effect of integrating local ethnomathematics based on Artificial Intelligence (AI) on students' mathematical critical thinking skills. The research employed a quantitative approach with a quasi-experimental design using a non-equivalent control group design. The study was conducted at SMA Negeri 3 Maros, involving 54 eleventh-grade students divided into an experimental class (27 students) and a control class (27 students). The experimental class received mathematics instruction through the integration of local ethnomathematics supported by an AI-based adaptive learning system, while the control class was taught using conventional methods. Data were collected using a critical thinking test administered as pretest and posttest, based on indicators of analysis, evaluation, inference, and conclusion. The results revealed that the experimental class achieved a higher mean posttest score (88.40) compared to the control class (83.20). The N-Gain score of the experimental class (0.78; very high category) was also greater than that of the control class (0.68; high category). Independent samples t-test indicated a significant difference between the two groups ($p < 0.05$). These findings demonstrate that integrating local ethnomathematics with AI significantly enhances students' mathematical critical thinking skills and provides an innovative, contextual, and adaptive learning alternative.

INTRODUCTION

Critical thinking skills constitute one of the essential competencies that students must possess in order to face the challenges of the twenty-first century. In the context of mathematics education, critical thinking is not merely related to the ability to solve problems procedurally, but also encompasses the capacity to analyze problems, evaluate solution strategies, draw logical inferences, and formulate conclusions in a rational and systematic manner (Latifah & Susanto, 2024). Therefore, fostering students' critical thinking skills has become a crucial demand in mathematics instruction at the senior high school level (Aini et al., 2023).

However, the reality of mathematics instruction in schools indicates that learning processes remain predominantly oriented toward mastering formulas and completing routine exercises (Ardi et al., 2024). Students tend to function primarily as passive recipients of

information, while teachers assume a central role in classroom instruction (Nabilla Calista Putri Susanto et al., 2022). This condition contributes to students' relatively low critical thinking skills, as they are insufficiently trained to connect mathematical concepts with real-life contexts and are rarely provided with opportunities to explore various problem-solving strategies (Farah et al., 2024). A similar phenomenon has been observed at SMA Negeri 3 Maros, Kabupaten Maros, where mathematics instruction continues to be dominated by conventional approaches and has not yet optimally fostered students' higher-order thinking skills (Sambara & Sape, 2023).

One approach considered promising for enhancing critical thinking skills is ethnomathematics (Putri Susanto et al., 2022). Ethnomathematics views mathematics as an integral part of culture and human activities, allowing mathematical concepts to be contextualized through local cultural practices that are closely related to students' daily lives (Sape & Syamsuddin, 2025; Muhammad et al., 2023). Kabupaten Maros possesses rich cultural traditions and community activities embedded with mathematical elements, such as geometric patterns in traditional houses, indigenous measurement systems, and local economic and craft practices. The integration of local ethnomathematics into mathematics instruction enables students to develop a more meaningful understanding of concepts, as learning originates from familiar experiences and environments.

On the other hand, the advancement of digital technology, particularly Artificial Intelligence (AI), offers substantial opportunities for innovation in mathematics education (Lukman et al., 2025). AI technology can provide adaptive learning systems that adjust instructional materials, levels of difficulty, and feedback according to students' needs and abilities (Firdaus & Sape, 2024). The utilization of AI in education functions not merely as a supporting medium, but also as a facilitator that encourages students to think critically through error analysis, strategy evaluation, and independent reflection on their learning processes (Sape et al., 2025).

Although ethnomathematics and AI technology have each been widely examined in the context of mathematics education, studies integrating local ethnomathematics with AI simultaneously remain relatively limited, particularly at the senior high school level. In fact, the integration of these two approaches has the potential to create mathematics instruction that is contextual, adaptive, and oriented toward the development of critical thinking skills. Ethnomathematics provides meaningful cultural contexts, while AI offers technological support that promotes active and personalized learning.

Based on preliminary observations and empirical findings, mathematics instruction at SMA Negeri 3 Maros has not yet fully integrated local cultural potential and digital technology. This condition has contributed to the suboptimal development of students' critical thinking skills, particularly in solving non-routine mathematical problems. Therefore, an instructional innovation is required to bridge local cultural contexts with modern technological advancements, ensuring that mathematics learning becomes more relevant, challenging, and meaningful for students.

Accordingly, this study focuses on the integration of local ethnomathematics based on Artificial Intelligence (AI) in mathematics instruction as an effort to enhance the critical thinking skills of students at SMA Negeri 3 Maros. This research is expected to contribute theoretically to the development of contextual, technology-based mathematics learning models and practically to assist teachers in designing innovative and adaptive instruction aligned with students' characteristics and local cultural values.

METHODS

This study employed a quantitative approach with a quasi-experimental design. The research design applied was the Non-Equivalent Control Group Design, involving two groups: an experimental class and a control class. Both groups were administered a pretest and a posttest to measure changes in students' critical thinking skills following the implementation of the treatment. The study was conducted at SMA Negeri 3 Maros, Kabupaten Maros, South

Sulawesi Province. The population consisted of all eleventh-grade students of SMA Negeri 3 Maros. The sample was selected using purposive sampling, considering the equivalence of academic characteristics and the readiness of learning facilities. Class XI.3 was designated as the experimental group, consisting of 27 students, while Class XI.4 was assigned as the control group, also comprising 27 students.

The experimental group received mathematics instruction through the integration of local ethnomathematics based on Artificial Intelligence (AI). The local ethnomathematical contexts were embedded into the mathematics learning materials, enabling students to engage with mathematical problems derived from local cultural practices and community activities. The integration of AI technology was implemented in the form of an adaptive learning system. The instructional design encouraged students to perform analysis, evaluate strategies, and draw conclusions as integral components of the critical thinking process. Meanwhile, the control group participated in conventional mathematics instruction without the integration of local ethnomathematics or AI technology.

The research instrument used in this study was a mathematical critical thinking test. The test consisted of essay-type questions developed based on critical thinking indicators, including the ability to analyze problems, evaluate solution strategies, draw inferences, and formulate conclusions from problem-solving processes. Data collection was conducted through the administration of pretests and posttests in both the experimental and control groups. The data obtained were analyzed using descriptive statistics to describe students' critical thinking skills and inferential statistics to test the research hypotheses. Prerequisite tests included tests of normality and homogeneity of variance.

RESULTS AND DISCUSSION

The findings of this study were derived from the analysis of students' mathematical critical thinking skills data collected through pretest and posttest assessments administered to both the experimental and control groups. The data were analyzed using descriptive and inferential statistics in accordance with the quasi-experimental design applied in this research.

Results of the Descriptive Analysis of Critical Thinking Skills

Based on the results of the descriptive analysis, an overview of students' critical thinking skills prior to the integration of ethnomathematics based on Artificial Intelligence (AI) was obtained. The initial critical thinking skills (pretest scores) of students in the experimental class are presented in the following table:

Table 1. Pretest Scores of Critical Thinking Skills in the Experimental Class

Descriptive Statistics	Pretest Score	Posttest Score
Sample Size (N)	27	27
Mean	46,30	88,40
Median	46,00	88,00
Mode	45,00	90,00
Standard Deviation	3,21	3,78
Variance	10,30	14,29
Skewness	0,28	0,12
Range	11	13
Minimum Value	41	82
Maximum Value	52	95

Based on Table 1, the pretest scores of students' critical thinking skills in the experimental class (N = 27) show a mean score of 46.30. This value indicates that, prior to the treatment, students' critical thinking skills were generally in the low to moderate category, thus requiring more innovative instructional efforts to achieve improvement.

The median score of 46.00 and the mode of 45.00, which are relatively close to the mean, indicate that the distribution of pretest scores was fairly even and did not exhibit extreme deviations. This suggests that most students had relatively similar initial levels of critical thinking skills.

Furthermore, the standard deviation of 3.21 and variance of 10.30 indicate that the distribution of scores was relatively homogeneous, meaning that differences in students' critical thinking skills before the treatment were not substantial. This condition provided a solid foundation for implementing the instructional intervention, as students began from relatively comparable baseline levels.

The skewness value of 0.28 indicates a slightly positive skew; however, the distribution remained within the normal range. Thus, the pretest data for students' critical thinking skills met the assumption of normality descriptively.

The score range of 11, with a minimum score of 41 and a maximum score of 52, reflects some variation in students' initial critical thinking skills, although the variation remained within reasonable limits. Overall, these descriptive statistical results indicate that the critical thinking skills of students in the experimental class prior to the implementation of local ethnomathematics integrated with Artificial Intelligence (AI) were not yet optimal and required a systematically designed instructional intervention.

In contrast, the posttest scores of students' critical thinking skills in the experimental class (N = 27) yielded a mean score of 88.40. This mean score demonstrates that, after the implementation of mathematics instruction integrating local ethnomathematics based on Artificial Intelligence (AI), students' critical thinking skills increased significantly and reached a high category. The median score of 88.00 and the mode of 90.00, which are relatively close to the mean, indicate that the distribution of posttest scores was fairly symmetrical and evenly distributed. This suggests that the majority of students achieved a high level of critical thinking skills after the treatment, rather than the improvement being limited to only a small number of students.

The standard deviation of 3.78 and variance of 14.29 indicate that the distribution of scores remained within a controlled and relatively homogeneous range. Although differences in ability among students were observed, these differences reflected individual development following a more challenging and critical-thinking-oriented learning process. The skewness value of 0.12 indicates that the data distribution was close to normal and did not exhibit significant deviation. This suggests that the posttest data met the assumption of normality descriptively and were appropriate for further analysis using parametric statistical tests.

The score range of 13, with a minimum score of 82 and a maximum score of 95, indicates that all students achieved relatively high scores. The absence of low scores in the posttest results suggests that the integration of local ethnomathematics based on AI effectively promoted a comprehensive improvement in critical thinking skills among students in the experimental class.

Overall, the descriptive statistical results of the posttest reinforce the finding that the integration of local ethnomathematics based on Artificial Intelligence (AI) had a strong positive impact on improving the critical thinking skills of students at SMA Negeri 3 Maros.

Table 2. Pretest Scores of Critical Thinking Skills in the Control Class

Descriptive Statistics	Pretest Score	Posttest Score
Sample Size (N)	27	27
Mean	46,80	83,20
Median	47,00	83,00
Mode	46,00	82,00
Standard Deviation	2,94	4,12
Variance	8,64	16,97
Skewness	0,19	0,35
Range	9	14
Minimum Value	43	77
Maximum Value	52	91

Based on Table 2, the pretest scores of students' critical thinking skills in the control class (N = 27) show a mean score of 46.80. This value indicates that students' critical thinking skills prior to instruction were in the low to moderate category and therefore required further enhancement through more effective instructional strategies.

The median score of 47.00 and the mode of 46.00, which are relatively close to the mean, indicate that the distribution of pretest scores in the control class was fairly even and did not exhibit extreme deviations. This suggests that most students had relatively similar initial levels of critical thinking skills.

The standard deviation of 2.94 and variance of 8.64 indicate that the distribution of critical thinking scores in the control class was relatively homogeneous. In other words, the differences in students' critical thinking skills before the treatment were not substantial, meaning that the initial condition of the control class can be considered stable and comparable to that of the experimental class.

The skewness value of 0.19 indicates a slightly positive skew; however, the distribution remained within the normal range. This suggests that the pretest data for the control class met the assumption of normality descriptively and were appropriate for further analysis using parametric statistical tests.

The score range of 9, with a minimum score of 43 and a maximum score of 52, reflects some variation in students' initial critical thinking skills, although the variation remained within reasonable limits. Overall, these descriptive statistical results indicate that the critical thinking skills of students in the control class prior to the treatment were not yet optimal and were relatively comparable to those of the experimental class, allowing for a fair comparison between the two groups in this study.

Regarding the posttest scores of critical thinking skills in the control class, the mean score was 83.20 (N = 27). This mean indicates that after participating in conventional mathematics instruction, students' critical thinking skills improved and reached a moderate to high category.

The median score of 83.00 and the mode of 82.00, which are relatively close to the mean, indicate that the distribution of posttest scores in the control class was fairly even. This suggests that the improvement in critical thinking skills was not limited to a small number of students but occurred relatively broadly within the class.

The standard deviation of 4.12 and variance of 16.97 indicate that the distribution of posttest scores showed greater variability compared to the pretest condition. This variation suggests that students responded differently to conventional instruction, resulting in improvements in critical thinking skills that were not entirely uniform.

The skewness value of 0.35 indicates a slightly positive skew, yet it remains within acceptable limits and close to a normal distribution. Therefore, the posttest data for the control class met the assumption of normality descriptively and were suitable for further analysis using parametric statistical tests.

The score range of 14, with a minimum score of 77 and a maximum score of 91, indicates variation in students' critical thinking skills after instruction. Although an overall improvement was observed, differences in achievement among students remained, suggesting that conventional instruction did not fully optimize the development of critical thinking skills in a uniform manner.

Overall, these descriptive statistical findings indicate that conventional instruction was able to improve the critical thinking skills of students in the control class; however, the improvement was not as optimal as that achieved through the integration of local ethnomathematics based on Artificial Intelligence (AI) implemented in the experimental class.

Table 3. N-Gain Calculation Results of Critical Thinking Skills

Class	Mean Pretest	Mean Posttest	Maximum Score	N-Gain	Category
Experimental	46,30	88,40	100	0,78	Very High
Control	46,80	83,20	100	0,68	High

The N-Gain value in the experimental class was 0.78, which falls into the very high category. This result indicates that mathematics instruction through the integration of local ethnomathematics based on Artificial Intelligence (AI) was highly effective in improving students' critical thinking skills. In contrast, the N-Gain value in the control class was 0.68, which is categorized as high. This finding shows that conventional mathematics instruction was still capable of improving students' critical thinking skills. However, when compared to the experimental class (N-Gain = 0.78, very high category), the improvement observed in the control class was relatively lower. This further supports the assumption that the integration of local ethnomathematics based on Artificial Intelligence (AI) provides a more effective instructional impact.

Inferential Statistical Analysis

Results of Prerequisite Tests

Prerequisite tests were conducted to ensure that the data on students' critical thinking skills met the statistical assumptions before testing the research hypothesis using parametric statistics. The prerequisite tests included tests of normality and homogeneity of variance.

Table 4. Results of the Normality Test of Critical Thinking Skills Data

Class	Statistic	Sig. (p-value)	Criteria
Experimental	0,961	0,318	Normal
Control	0,954	0,247	Normal

Based on Table 4, the results of the normality test using the Shapiro–Wilk test indicate that the posttest data on critical thinking skills in the experimental class obtained a significance value of 0.318, while the control class obtained a significance value of 0.247. Both significance values are greater than 0.05; therefore, it can be concluded that the posttest data in both classes are normally distributed.

Table 5. Results of the Homogeneity of Variance Test for Posttest Data

Tested Data	Statistic Levene	Sig. (p-value)	Criteria
Experimental & Control	0,842	0,363	Homogen

Furthermore, based on Table 5, the results of the homogeneity of variance test using Levene's test show a significance value of 0.363, which is also greater than 0.05. This indicates that the variance of the critical thinking skills data between the experimental and control classes is homogeneous.

Since the assumptions of normality and homogeneity have been satisfied, the research data meet the requirements for analysis using parametric statistical tests, specifically the independent samples t-test, in order to examine the research hypothesis concerning the effect of integrating local ethnomathematics based on Artificial Intelligence (AI) on the critical thinking skills of students at SMA Negeri 3 Maros.

Results of Hypothesis Testing

Hypothesis testing was conducted to determine whether there was a significant difference in the improvement of students' critical thinking skills between the class that received instruction through the integration of local ethnomathematics based on Artificial Intelligence (AI) and the class that received conventional instruction. The hypothesis was tested using an independent samples t-test on the posttest scores of critical thinking skills, as the data had satisfied the assumptions of normality and homogeneity.

Table 6. Results of the Independent Samples t-Test on Posttest Scores of Critical Thinking Skills

Class	N	Mean	Std. Deviation	t-value	Sig. (2-tailed)	Remark
Experimental	27	88,40	3,78	4,73	0,000	Significant
Control	27	83,20	4,12	4,73	0,000	Significant

Based on Table 6, the mean posttest score of students' critical thinking skills in the experimental class was 88.40, whereas the mean score in the control class was 83.20. This difference in mean scores indicates that students who participated in mathematics instruction through the integration of local ethnomathematics based on Artificial Intelligence (AI) demonstrated higher critical thinking skills than those who received conventional instruction.

The results of the independent samples t-test showed a t-value of 4.73 with a significance value of Sig. (2-tailed) = 0.000. This significance value is lower than the predetermined significance level of 0.05. Therefore, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted.

The rejection of the null hypothesis indicates that there is a statistically significant difference between the critical thinking skills of students in the experimental class and those in the control class. In other words, mathematics instruction through the integration of local ethnomathematics based on Artificial Intelligence (AI) had a significant effect on improving the critical thinking skills of students at SMA Negeri 3 Maros.

These findings suggest that the use of local ethnomathematical contexts closely related to students' daily lives, combined with adaptive AI technology that provides immediate instructional feedback, effectively encourages students to engage more actively in analyzing problems, evaluating solution strategies, and drawing logical conclusions. In contrast, although conventional instruction was able to improve critical thinking skills, it did not produce an impact comparable to that of the innovative approach integrating ethnomathematics and Artificial Intelligence (AI).

Based on the results of the hypothesis testing, it can be concluded that the integration of local ethnomathematics based on Artificial Intelligence (AI) is significantly more effective in enhancing students' critical thinking skills than conventional mathematics instruction.

Discussion of Research Findings

The findings indicate that the integration of local ethnomathematics based on Artificial Intelligence (AI) had a significant effect on improving students' critical thinking skills. Quantitatively, the difference in posttest mean scores between the experimental class (88.40) and the control class (83.20), as well as the higher N-Gain value in the experimental class (0.78; very high category) compared to the control class (0.68; high category), confirms that the instructional intervention was not only effective but also produced a more optimal improvement. These findings address the primary objective of the study, namely to examine the effectiveness of integrating local ethnomathematics based on AI in enhancing the critical thinking skills of students at SMA Negeri 3 Maros.

When analyzed based on critical thinking indicators—problem analysis, strategy evaluation, drawing inferences, and concluding solutions—the most prominent improvement in the experimental class was observed in the aspects of analysis and strategy evaluation. This can be explained by the ethnomathematics-based approach, which presents real contexts derived from local culture that are closely related to students' lived experiences. When students are confronted with contextual problems, they are not merely recalling formulas; instead, they are encouraged to understand the structure of the problem, identify relevant information, and compare alternative solution strategies. This process naturally activates higher-order thinking mechanisms.

The integration of AI further strengthened this process through an adaptive system that provided immediate feedback and specific error analysis. When students made mistakes, the system did not simply display the correct answer but guided them to reflect on inaccurate

steps. Consequently, the improvement was not merely procedural but metacognitive in nature. Students learned “why” a strategy was correct or incorrect, rather than simply “what” the answer was. Theoretically, this condition aligns with the constructivist framework, which emphasizes that knowledge is constructed through active experience and reflection.

In the control class, improvement also occurred because conventional instruction still provided practice and reinforcement of concepts. However, the greater score variation and lower average achievement indicate that this approach did not fully facilitate the balanced development of critical thinking indicators. Students tended to be stronger in procedural problem-solving but less optimal in strategy evaluation and inference. In other words, they could produce answers but were not necessarily able to explain the logical reasoning behind them.

Why is the integration of local ethnomathematics based on AI more effective? First, cultural context enhances relevance and students’ intrinsic motivation. When mathematics is connected to familiar socio-cultural realities, learning becomes meaningful. Second, AI provides personalized instruction, ensuring that each student receives challenges appropriate to their level of ability. The combination of meaningful context and technological adaptability creates a learning environment that stimulates in-depth analysis, reflection, and logical argumentation-core elements of critical thinking.

From a problem-solving theory perspective, these findings can also be explained through the stages proposed by George Polya: understanding the problem, devising a plan, carrying out the plan, and looking back. Ethnomathematics- and AI-based instruction systematically facilitates all four stages. Students do not merely stop at obtaining solutions; they are also encouraged to reflect on their results. This reflective process strengthens inference and evaluative skills.

The results of this study are consistent with the findings of Sape (2025), which revealed that AI-based learning effectively improves numeracy literacy and critical thinking skills through adaptive interactive systems. Additionally, Anggraeni and Supriadi (2025) demonstrated that ethnomathematics learning significantly enhances elementary students’ mathematical critical thinking skills by presenting authentic cultural contexts.

These findings are further supported by Pramasdyasari et al. (2024), who reported that integrating ethnomathematics into STEM-PjBL-based digital media significantly improves students’ critical thinking quality. Moreover, Prihono and Khasanah (2020) found that problem-based learning (PBL) enhances critical thinking skills through analytical and evaluative solution activities.

Furthermore, Muhammad Rizaldi et al. (2024) discovered that the use of AI tools such as ChatGPT in algebra learning encourages university students to think critically through reflective and exploratory dialogue. Conceptually, these studies reinforce the present findings that the combination of meaningful context (ethnomathematics) and adaptive technology (AI) creates an effective pedagogical synergy in developing critical thinking skills.

CONCLUSION

The integration of local ethnomathematics based on Artificial Intelligence (AI) in mathematics instruction significantly improves the critical thinking skills of students at SMA Negeri 3 Maros. This is evidenced by the higher posttest scores achieved by the experimental class compared to the control class, as well as the results of inferential statistical analysis indicating a significant difference. Instruction that connects local cultural contexts with the support of an adaptive AI system encourages students to analyze problems, evaluate strategies, draw inferences, and formulate logical conclusions. Therefore, this approach is effective as an innovative instructional alternative for developing students’ mathematical critical thinking skills.

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