Implementation of AI Interactive to Improve Mathematics Learning Outcomes Viewed from Students' Learning Independence

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Abstract: This study aims to examine the implementation of AI-based interactive technology in improving mathematics learning outcomes viewed from students' learning independence. The research was conducted at SMPN 1 Nanga Pinoh with a sample of 32 students from grade VII. This research employed a quantitative methodology utilizing a single-group pre-post experimental design. Data collection instruments comprised an achievement test and a self-directed learning questionnaire. Statistical analysis was conducted through paired-samples t-test and one-way analysis of variance (ANOVA). The paired-samples t-test yielded a p-value < 0.05, demonstrating a statistically significant difference between participants' pre-intervention and post-intervention scores. These findings confirm that the integration of artificial intelligence-driven interactive technology produced substantial improvements in students' mathematical achievement. Furthermore, the one-way ANOVA test produced a significance value of 0.186 (> 0.05), indicating that there was no significant difference in learning outcomes among students with high, medium, and low learning independence levels. Thus, students' learning independence did not significantly influence mathematics learning outcomes after the use of AI-based interactive technology. In conclusion, AI-based interactive technology can enhance students' mathematics learning outcomes overall, although the effect does not significantly differ when viewed from the level of learning independence. Future research is suggested to integrate motivational or self-regulated learning strategies to strengthen the influence of learning independence in technology-assisted learning.

Keyword: AI; Learning Independence; Mathematics Learning Outcomes

Introduction

The advancement of Artificial Intelligence (AI) has generated substantial transformations in mathematics education, with interactive technologies such as Intelligent Tutoring Systems (ITS) and adaptive learning environments providing personalized and responsive educational experiences (Awang et al., 2025; Wijaya et al., 2024). However, mathematics education in Indonesia continues to face fundamental challenges. The Programme for International Student Assessment (PISA) 2022 data reveal that Indonesian students aged 15 scored 366 in mathematics, significantly below the OECD average of 472 (Lestari et al., 2025). Traditional teacher-directed methods dominate Indonesian classrooms, failing to develop students' capacity to connect mathematical concepts with real-life contexts and hindering critical thinking development (Anugraheni et al., 2025; Salsabila et al., 2025).

These challenges are compounded by low levels of student learning independence—defined as students' capacity to regulate their cognition, motivation, and behavior in learning (Kholid & Naufan, 2025). Students with strong self-regulated learning (SRL) strategies typically demonstrate superior academic achievement and enhanced metacognitive abilities (Siregar et al., 2022). Unfortunately, instructional practices remain procedural with limited teacher digital literacy, inadequate interdisciplinary collaboration, and a lack of adaptive platforms that constrain educational reform implementation (Yulianto & Juniawan, 2025).

AI-based interactive technology has emerged as a promising solution, offering real-time feedback, personalized exercises, and interactive visualizations that facilitate understanding of abstract concepts (Awang et al., 2025). This technology possesses considerable potential to enhance personalized learning and foster more engaging environments through adaptive pathways and data-driven instructional decisions (Msomi & Mthethwa, 2024; Opesemowo & Ndlovu, 2024). The theoretical foundation integrates three complementary frameworks: (1) Zimmerman's Self-Regulated Learning theory, emphasizing that self-regulated learners employ strategies to optimize their learning processes (Kholid & Naufan, 2025; Wang & Sperling, 2020); (2) AI-based adaptive learning principles, demonstrated through systems like ALEKS, GeoGebra Tutor, and MATHia that provide individualized pathways using expert systems and neural networks (Awang et al., 2025); and (3) social constructivist theory, underscoring the role of interaction in knowledge construction.

Empirical evidence increasingly confirms AI's positive impact on mathematics learning. Systematic analyses reveal that AR/VR applications and AI-based feedback tools enhance motivation, problem-solving skills, and achievement through adaptive guidance (Awang et al., 2025). Metacognitive-oriented interventions integrating cognitive and motivational strategies effectively enhance both achievement and SRL capacities. However, critical gaps persist in the literature. Most studies explore general AI categories without adequately specifying tools and functions, leaving practitioners without practical guidance (Awang et al., 2025).

More critically, few studies examine how students' learning independence levels moderate AI effectiveness in mathematics learning, particularly in Indonesian contexts. Additionally, while students' AI literacy grows, concerns emerge about technology dependence potentially undermining essential 21st-century skills such as problem-solving, creativity, and critical thinking (Wijaya et al., 2024).

Implementation challenges in Indonesia include time and resource constraints (71.34% of identified factors), inadequate pedagogical expertise, and limited teacher confidence with specific mathematics tools like GeoGebra (Hidayat & Chao, 2025; Trisnani et al., 2024). Despite awareness of digital tools, teachers frequently lack strategies to effectively integrate them for enhanced student engagement. Therefore, research exploring AI implementation that considers individual characteristics particularly learning independence is urgently needed.

This study investigates how AI-based interactive technology influences mathematics learning outcomes when viewed through the lens of students' learning independence. Specifically, this research seeks to: (1) examine whether significant differences exist in students' learning outcomes before and after AI-based interactive technology application; (2) analyze whether differences in mathematics learning outcomes exist among students with high, medium, and low learning independence levels after using AI-based interactive technology; and (3) provide practical recommendations for educators and policymakers regarding optimal AI integration strategies.

This study offers significant contributions. Theoretically, it enriches technology-based mathematics learning literature by exploring learning independence as a moderating variable in AI contexts, providing deeper understanding of psychological mechanisms underlying adaptive learning effectiveness. Practically, findings will provide empirical insights for mathematics teachers, educational technology developers, and policymakers in designing AI-assisted learning that enhances both academic achievement and learning independence. AI technology transforms not only how students learn mathematics but also encourages educators to rethink critical content and real-world applications (Aldyandra et al., 2024). Thus, this research contributes to advancing mathematics education transformation in Indonesia toward more innovative, inclusive, and student-centered learning.

Methods

This research used a quasi-experimental pretest–posttest control group design involving eighth-grade students from SMPN 1 Nanga Pinoh (2025/2026). Cluster random sampling was applied to select participants. The experimental class received AI-integrated interactive mathematics instruction, while the control class followed conventional expository teaching.

The research instruments consisted of a mathematics learning achievement test and a learning independence questionnaire, both developed based on the basic competency indicators of the taught material and the indicators of learning independence. The data in this study were obtained from students' pretest and posttest results, as well as responses to the learning independence questionnaire. The data collection process was carried out in three stages: (1) Administering the pretest to identify students' initial ability levels, (2) Implementing the learning treatments according to each class condition (experimental and control) over four meetings, and (3) Administering the posttest and distributing the learning independence questionnaire at the end of the learning sessions.

Hendriana et al., (2017), identify the indicators of self-regulated learning (SRL) as comprising (1) independence from others, (2) self-confidence, (3) disciplined behavior, (4) initiative, (5) self-control, and (6) a sense of responsibility. Similarly, Barry J. Zimmerman & Schunk (2001), classify SRL indicators into three domains: (1) metacognition, which includes planning, goal setting, self-monitoring, and self-evaluation; (2) motivation, referring to the effort and self-efficacy to improve learning performance; and (3) behavior, which involves creating a conducive environment that supports learning. Meanwhile, Mudjiman (2011), highlights five indicators of SRL, namely self-confidence, learning discipline, activeness in learning, responsibility, and motivation.

In this study, the learning independence questionnaire was developed by adapting these frameworks to include five main indicators: (1) self-confidence, (2) motivation, (3) initiative and independence in learning, (4) discipline and responsibility, and (5) self-monitoring and evaluation. These indicators were operationalized into twenty statements reflecting students' attitudes and behaviors in learning mathematics. Data analysis involved the Kolmogorov–Smirnov test to assess normality and the Levene test to evaluate homogeneity, ensuring that statistical assumptions were satisfied. Subsequently, a paired-sample t-test was employed to compare learning outcomes between the experimental and control groups. Furthermore, a one-way ANOVA was performed to assess the effect of AI-based interactive learning implementation on mathematics achievement across varying levels of students' learning independence.

Results And Discussion

Results

a. Prerequisite Test Results (Normality and Homogeneity)

Before conducting inferential analyses, preliminary tests were carried out to ensure that the data met the assumptions of parametric statistics. The Kolmogorov-Smirnov test for normality produced significance values of 0.085 for the pre-test and 0.099 for the post-test, both greater than 0.05, indicating that the data were normally distributed. Moreover, Levene's Test for homogeneity yielded a significance value of 0.468 > 0.05, confirming that the variances between groups were homogeneous. Therefore, the data fulfilled the requirements for subsequent t-test and ANOVA analyses. The detailed results of these prerequisite tests are presented in Table 1 and Table 2.

Table 1. SPSS Normality Test Results (Kolmogorov–Smirnov)

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test Pecahan	.145	32	.085	.934	32	.051
Post-test Pecahan	.142	32	.099	.938	32	.066

a. Lilliefors Significance Correction

Table 2. SPSS Homogeneity Test Results (Levene's Statistic)

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Hasil Belajar Siswa	Based on Mean	.780	2	29	.468
	Based on Median	1.009	2	29	.377
	Based on Median and with adjusted df	1.009	2	28.523	.377
	Based on trimmed mean	.856	2	29	.435

b. T-Test Results on Students' Mathematics Learning Outcomes

A paired-sample t-test was then employed to assess changes in students' mathematics achievement following the implementation of AI-based interactive technology. The corresponding results are summarized in Table 3.

Table 3. SPSS Paired Sample Test Results

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Pre-test Pecahan - Post-test Pecahan	-20.781	10.582	1.871	-24.597	-16.966	-11.109	31	.000

A paired-sample t-test was conducted to determine the differences in students' mathematics learning outcomes before and after the implementation of AI-based interactive technology. The statistical hypotheses established for this analysis are presented as follows:

H_0: There is no difference in students' mathematics learning outcomes before and after the implementation of AI-based interactive technology.

H_1: There is a difference in students' mathematics learning outcomes before and after the implementation of AI-based interactive technology.

The results of the paired-sample t-test indicated a significance value of 0.000 < 0.05, resulting in the rejection of H_0 and the acceptance of H_1. This indicates a significant difference between students' pretest and posttest mathematics learning scores. The mean posttest score of 87 exceeded the pretest mean of 66, demonstrating an improvement in learning outcomes following the implementation of AI-based interactive technology.

These results indicate that the use of AI-based interactive technology has a positive effect on improving students' mathematics learning outcomes. This finding is consistent with Arya et al., (2023), who stated that the application of artificial intelligence in learning can enhance student engagement and deepen conceptual understanding. Therefore, the implementation of AI-based interactive technology has been proven effective in improving the mathematics learning outcomes of Grade VII students at SMPN 1 Nanga Pinoh.

c. ANOVA Test Results on Learning Outcomes and Learning Independence

Following the confirmation of an overall enhancement in mathematics learning outcomes via a paired sample t-test, a subsequent analysis was performed to investigate potential differences in students' mathematics learning outcomes relative to their levels of learning independence. To this end, a One-Way ANOVA (Analysis of Variance) was employed to compare the mean learning outcomes across three categories of learning independence: high, medium, and low. The findings from the One-Way ANOVA test are detailed in Table 4 below:

Table 4. SPSS One-Way ANOVA Test Results

ANOVA

Hasil Belajar Siswa

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	53.397	2	26.699	1.786	.186
Within Groups	433.478	29	14.948		
Total	486.875	31			

As shown in Table 4, the calculated F value was 1.786 with a corresponding significance (Sig.) value of 0.186. Since the significance value exceeds the 0.05 threshold, the null hypothesis (H_0) is accepted and the alternative hypothesis (H_1) is rejected. This indicates that no significant differences exist in mathematics learning outcomes among students with high, medium, and low levels of learning independence after the implementation of AI-based interactive technology. To validate this result and identify potential differences between specific groups, a post hoc analysis was conducted using the Tukey HSD (Honestly Significant Difference) method. The outcomes of the Tukey HSD test are presented in Table 5.

Table 5. Tukey Post Hoc Test Results

Multiple Comparisons

Dependent Variable: Hasil Belajar Siswa
Tukey HSD

(I) Kemandirian Belajar	(J) Kemandirian Belajar	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tinggi	Sedang	1.278	1.578	.700	-2.62	5.18
	Rendah	-2.789	1.954	.341	-7.62	2.04
Sedang	Tinggi	-1.278	1.578	.700	-5.18	2.62
	Rendah	-4.067	2.156	.161	-9.39	1.26
Rendah	Tinggi	2.789	1.954	.341	-2.04	7.62
	Sedang	4.067	2.156	.161	-1.26	9.39

Based on Table 5, it can be observed that all group comparisons show significance values greater than 0.05. The comparison between the high and medium learning independence groups yielded a Sig. value of 0.700 > 0.05, the comparison between the high and low groups produced a Sig. value of 0.341 > 0.05, and the comparison between the medium and low groups resulted in a Sig. value of 0.161 > 0.05. This indicates that there are no pairs of groups with statistically significant differences in learning outcomes.

These findings indicate that following the implementation of AI-based interactive technology, the levels of learning independence among students did not significantly influence their mathematics learning outcomes. In other words, students categorized as having high, medium, and low levels of learning independence exhibited relatively comparable improvements in their learning outcomes after utilizing AI-based interactive technology in mathematics instruction.

This result implies that AI-based interactive technology has the capability to provide effective learning support to all students, regardless of their level of learning independence. This is consistent with Maulidin (2024), who explains that AI technology, being adaptive in nature, provides scaffolding (tiered support) tailored to each student's individual needs. AI technology can adjust the level of difficulty, pace of learning, and deliver personalized feedback, enabling students with lower learning independence to still engage effectively in the learning process.

Discussion

This study aimed to analyze the implementation of AI-based interactive technology in improving mathematics learning outcomes in relation to students' learning independence. Based on the data analysis presented, two main findings emerged that require in-depth discussion: (1) AI-based interactive technology significantly improves students' mathematics learning outcomes; and (2) students' levels of learning independence do not have a significant effect on their mathematics learning outcomes after the implementation of the technology. These two findings carry important theoretical and practical implications for the development of technology based mathematics instruction.

The initial results show a statistically significant enhancement in students' mathematics achievement after the integration of AI-based interactive technology, with a significance level of 0.000, which is below 0.05. The average score rose from 66 in the pretest to 87 in the posttest, reflecting an improvement of 21 points, or approximately 31.8%. This notable enhancement underscores the positive and significant impact of AI-based interactive technology on the mathematics achievement of Grade VII students at SMPN 1 Nanga Pinoh, particularly concerning the topic of fractions.

This result aligns with the findings of Muin & Kusmaladewi (2025), who stated that the application of artificial intelligence in learning can enhance student engagement and deepen conceptual understanding. The advantage of AI technology in the context of mathematics learning lies in its ability to provide an interactive, visual, and adaptive learning experience. In this study, students used AI technology to explore fraction concepts through interactive simulations and practice exercises. The significant improvement in learning outcomes can be explained through several psychological and pedagogical mechanisms. First, AI technology provides immediate feedback, allowing students to quickly identify their mistakes and make corrections. This aligns with the principle of formative assessment, which emphasizes the importance of continuous feedback in the learning process (Arta, 2024).

Second, AI technology offers adaptive learning pathways that adjust the difficulty level of the material according to students' abilities. In line with the research of Wahyudi et al., (2025), this adaptive approach implements Vygotsky's concept of the Zone of Proximal Development (ZPD), in which effective learning occurs when students are given challenges slightly above their current ability level with sufficient support. Third, the gamification and interactivity elements in AI technology increase students' motivation and engagement in learning (Azim et al., 2025). Features such as points, badges, progressive difficulty levels, and engaging animations create a more enjoyable and immersive learning experience.

However, it is important to note that the effectiveness of AI technology does not occur automatically. The success of its implementation in this study was also supported by the teacher's role as a facilitator who guided students in using the technology, asked reflective questions, and connected mathematical concepts with real-life contexts. This emphasizes the importance of integrating technology within a well-designed pedagogical framework, rather than merely introducing technology without clear instructional objectives.

The second finding, which is equally noteworthy, reveals that there was no significant difference in mathematics learning outcomes among students with high, medium, and low levels of learning independence after the implementation of AI-based interactive technology ($F = 1.786$; Sig. = $0.186 > 0.05$). The Tukey HSD post hoc test also confirmed that all pairwise group comparisons (high–medium, high–low, and medium–low) showed no significant differences. This finding is quite surprising and differs from the initial research hypothesis, which anticipated that students with high learning independence would perform better than those with low independence. It also contrasts with previous studies showing a positive correlation between self-regulated learning and academic achievement (Kristayani, 2016).

Several alternative explanations can be proposed to understand this phenomenon. One possible explanation is the compensatory effect of AI technology, which may serve as a key factor. Adaptive AI technology that provides intensive scaffolding (tiered support) can compensate for students' lack of learning independence (Qiftiyah et al., 2025). Students with low learning independence, who typically require more external guidance, receive such support through AI features such as step-by-step instructions, detailed corrective feedback, and personalized repetition of learning materials. In other words, AI technology functions as an external regulator, substituting for the self-regulation skills that are not yet optimally developed in students with low learning independence (Kristayani, 2016).

This aligns with the findings of Maulidin (2024), who stated that adaptive AI technology can adjust the level of material difficulty, learning pace, and provide personalized feedback according to individual student needs. In the context of this study, the AI system used may have automatically identified students' learning difficulties and delivered timely interventions, allowing students with low learning independence to achieve learning outcomes comparable to those with higher independence.

Another possible explanation is that the relatively short research duration may not have been sufficient to capture the differential effects of learning independence on learning outcomes. A longitudinal study might be needed to determine whether differences in learning independence affect long-term retention and knowledge transfer. Furthermore, the instructional design of the AI technology used in this study may not have explicitly and systematically integrated strategies to develop and strengthen students' learning independence (Zila, 2025). Consistent with Maulidin (2024), although AI technology offers adaptive learning experiences, the system may still be reactive (responding to students' difficulties) rather than proactive (teaching self-regulated learning strategies). Research shows that to maximize the development of learning independence, educational technology should explicitly teach and train strategies such as goal setting, self-monitoring, self-evaluation, and reflection.

Additionally, teacher guidance and classroom context should also be considered (Zila, 2025). In this study, teachers provided relatively uniform guidance and direction to all students in using the AI technology. This consistent teacher support may have minimized differences between students with high and low learning independence, as all students received sufficient external regulation from the teacher. This highlights the importance of the teacher's role as a co-regulator in technology-enhanced learning (Yustiasari Liriwati, 2023).

The findings of this study make an important contribution to the literature on technology-based mathematics learning and self-regulated learning. First, this study provides empirical evidence that AI technology can effectively enhance mathematics learning outcomes in the context of Indonesian education, particularly at the junior high school level. This extends the ecological validity of previous studies, most of which were conducted in developed countries with more advanced technological infrastructures.

Second, the finding that there were no differences in learning outcomes based on learning independence challenges conventional assumptions about the role of individual characteristics in technology-based learning. This result suggests that with appropriate technology design especially one that is adaptive and provides sufficient scaffolding technology can serve as an equalizer, reducing learning outcome disparities typically associated with differences in learning independence. This aligns with the Universal Design for Learning (UDL) perspective, which emphasizes the importance of providing multiple means of engagement, representation, and action/expression to accommodate learner diversity (Saputra & Samudra, 2025).

From a practical perspective, this study offers several important implications for teachers, educational technology developers, and policymakers. First, AI-based interactive technology has been proven effective as a mathematics learning aid and can be integrated into classroom practice. Junior high school mathematics teachers can utilize AI technology to provide more interactive, visual, and adaptive learning experiences, particularly for challenging topics such as fractions.

Research Limitations

Although this study provides meaningful findings, several limitations should be acknowledged and considered for future research. First, this study employed a one-group pretest–posttest design without a control group. Although a significant improvement in learning outcomes was observed, it cannot be conclusively stated that this improvement was solely due to the AI technology, as other factors such as maturation effect, testing effect, or history effect could not be fully controlled. Future

studies should adopt a quasi-experimental or true experimental design with a control group to strengthen internal validity.
Second, the limited sample size (N = 32) sourced from a single school constrains the generalizability of the findings. To validate these results, replication studies involving larger and more diverse samples encompassing various schools, ability levels, and socio-economic background are essential. Third, the relatively brief duration of the intervention may not have been adequate to assess the long-term effects of AI technology on learning outcomes and learning independence. Longitudinal studies are recommended to investigate the sustained impact of AI technology on the development of students' learning independence over time. Fourth, this study focused exclusively on measuring cognitive learning outcomes through an achievement test. Future research should incorporate assessments of affective factors (such as motivation, self-efficacy, and attitudes toward mathematics) and behavioral factors (such as engagement and time on task) to provide a more holistic understanding of the influence of AI technology on student learning.

Conclusion

This study has several limitations that warrant consideration. The one-group pretest-posttest design without a control group limits causal inferences, as maturation and testing effects could not be fully controlled. The relatively small sample size (N = 32) from a single school restricts generalizability to broader populations. Additionally, the short intervention duration (four meetings) may have been insufficient to capture long-term effects on learning independence development or to observe differential impacts across independence levels that might emerge over extended periods. The study also focused solely on cognitive outcomes through achievement tests, without measuring affective factors such as motivation, self-efficacy, and attitudes toward mathematics, which could provide more comprehensive insights into AI technology's impact.

Future research should employ quasi-experimental or true experimental designs with control groups to strengthen internal validity and establish clearer causal relationships. Studies involving larger, more diverse samples across multiple schools, geographic regions, and socioeconomic backgrounds would enhance generalizability. Longitudinal investigations are essential to examine the sustained effects of AI technology on both learning outcomes and the progressive development of learning independence over time. Furthermore, future studies should incorporate mixed-methods approaches that assess not only cognitive outcomes but also affective dimensions (motivation, self-efficacy, mathematical anxiety) and behavioral indicators (engagement patterns, time-on-task, persistence). Critically, research should explore AI systems that explicitly and systematically integrate self-regulated learning instruction such as prompts for goal-setting, self-monitoring reminders, and guided reflection activities to determine whether such features can enhance the development of learning independence alongside academic achievement.

In conclusion, AI-based interactive technology demonstrates significant potential for improving mathematics learning outcomes across diverse student populations. With appropriate teacher preparation, thoughtful pedagogical integration, and explicit attention to developing students' self-regulatory capacities, AI can serve not merely as a tool for enhancing academic performance but as a catalyst for fostering lifelong learning skills and student agency in mathematics education.

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