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Effectivity of Artificial Intelligence-Assisted Learning on Elementary School Students' Mathematical Problem-Solving Ability

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Abstract: This study aims to test the effect of artificial intelligence-assisted learning on elementary school students' problem-solving abilities in mathematics learning. This study is a quantitative study with an experimental research type. The experimental design used is a quasi-experiment involving students of Blokang State Elementary School as an experimental class (totaling 30 students) and students of Batucina State Elementary School (totaling 30 students) as a control class. The data of this study is quantitative data collected using mathematical problem-solving ability test techniques. The collected data were then analyzed using descriptive statistical test techniques by testing the average value, standard deviation and percentage of completeness, as well as inferential statistical tests using independent t-tests and paired t-tests. The results of the study indicate that artificial intelligence-assisted learning has a positive and significant effect on elementary school students' problem-solving abilities in mathematics learning. This is evident from the research data which shows that the average value of students' mathematical problem-solving abilities in the experimental class is higher (92.16) than the control class (69.13). In addition, the standard deviation value also shows that the standard deviation value of the experimental class is smaller than the control class, which means that the mathematical problem-solving abilities The distribution of students in the experimental class was more even. Furthermore, the percentage of student completion showed that the experimental class achieved 95.61%, while the control class only achieved 70.33%. Inferential statistical tests were conducted in this study to test the research hypothesis. The results of the prerequisite test showed that the data were normally distributed (Sig. > 0.05) and the sample came from a homogeneous population (Sig. > 0.05). The results of the prerequisite test were used as the basis for continuing the hypothesis test using parametric statistical techniques with the t-test type. The results of the independent t-test and paired t-test showed that the significance value was smaller than the alpha value, which was 0.000 (<0.005). Based on these results, artificial intelligence-assisted learning can be used as an alternative to address the low problem-solving abilities of elementary school students in mathematics learning.

Keywords: Artificial intelligence-assisted learning, problem-solving ability, mathematics learning.

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INTRODUCTION

Mathematical problem-solving ability is widely recognized as one of the most essential competencies that elementary school students must develop in the twenty-first century. Beyond mastering computational procedures, students are expected to analyze situations, identify relevant information, formulate strategies, and evaluate solutions when confronted with mathematical problems. Problem-solving skills not only support academic achievement in mathematics but also contribute to the development of logical reasoning, critical thinking, creativity, and decision-making abilities that are required in contemporary society (National Council of Teachers of Mathematics [NCTM], 2023). Consequently, enhancing students' mathematical problem-solving ability has become a central objective of mathematics education across various educational systems worldwide.

The significance of mathematical problem-solving has been emphasized by numerous international educational frameworks. The Programme for International Student Assessment (PISA) identifies mathematical literacy as the capacity to formulate, employ, and interpret mathematics in various contexts, requiring students to engage in reasoning and problem-solving processes rather than merely applying memorized formulas (Organisation for Economic Co-operation and Development [OECD], 2023). Similarly, contemporary mathematics curricula advocate learning experiences that encourage students to investigate, explore, and solve authentic problems as a means of developing deeper conceptual understanding (Cai et al., 2022).

Despite its importance, many elementary school students continue to experience difficulties in solving mathematical problems effectively. Research has consistently shown that students often struggle to understand problem statements, identify appropriate solution strategies, and connect mathematical concepts with real-world situations (Tambychik & Meerah, 2019; Juandi et al., 2021). These challenges frequently result in low achievement levels and limited confidence when students encounter non-routine mathematical tasks. Such conditions indicate that the development of mathematical problem-solving ability remains a significant educational challenge.

The issue is particularly evident in developing countries, where mathematics achievement continues to lag behind international standards. Recent international assessments have revealed that many students demonstrate weaknesses in higher-order thinking skills, including reasoning, critical analysis, and problem-solving (OECD, 2023). In Indonesia, concerns regarding students' mathematical competence have prompted educators and policymakers to seek innovative instructional approaches capable of improving learning outcomes and fostering more meaningful engagement with mathematical concepts.

Several studies have indicated that traditional teacher-centered instructional practices remain dominant in many elementary school classrooms. In such environments, students often act as passive recipients of information, while teachers primarily focus on explaining procedures and providing examples for imitation (Hwang & Tu, 2021). Although this approach may facilitate procedural fluency, it frequently fails to cultivate the analytical and reflective thinking processes necessary for effective problem-solving. As a result, students may become dependent on routine procedures and encounter difficulties when facing unfamiliar problems.

The rapid advancement of digital technology has created new opportunities for transforming mathematics learning environments. Educational technologies have increasingly been utilized to support student-centered learning by providing interactive experiences, immediate feedback, and personalized instructional support (Bond et al., 2024). These technological innovations have the potential to promote deeper learning by enabling students to actively engage in exploration, experimentation, and problem-solving activities.

Among recent technological developments, artificial intelligence (AI) has emerged as one of the most influential innovations in education. Artificial intelligence refers to computer systems capable of performing tasks that typically require human intelligence, including learning, reasoning, decision-making, language processing, and pattern recognition (Luckin et al., 2022). The growing accessibility of AI-based educational tools has generated substantial interest among educators seeking to enhance teaching and learning processes.

Artificial intelligence offers several advantages that distinguish it from conventional educational technologies. AI systems can analyze student performance in real time, identify learning difficulties, adapt instructional content according to individual needs, and provide personalized feedback (Holmes et al., 2022). These capabilities align closely with contemporary educational goals that emphasize differentiated instruction and individualized learning pathways.

In mathematics education, AI-assisted learning has demonstrated considerable potential for supporting students' conceptual understanding and problem-solving development. AI-powered platforms can guide learners through complex tasks, provide hints tailored to specific misconceptions, and offer adaptive learning experiences that accommodate varying levels of prior knowledge (Zawacki-Richter et al., 2019). Such features may help students overcome learning obstacles more effectively than traditional instructional approaches.

The emergence of generative artificial intelligence technologies has further expanded educational possibilities. Applications such as intelligent tutoring systems, adaptive learning platforms, and AI-driven conversational agents can facilitate interactive learning experiences that encourage students to engage actively with mathematical concepts (Kasneci et al., 2023). These tools can support students in exploring multiple solution strategies, receiving immediate feedback, and refining their reasoning processes throughout problem-solving activities.

Recent empirical studies have reported positive outcomes associated with AI integration in educational settings. Research indicates that AI-assisted learning can improve academic achievement, learning motivation, engagement, and self-regulated learning among students across different educational levels (Chen et al., 2020; Ouyang et al., 2022). Furthermore, AI technologies have been shown to facilitate personalized learning experiences that contribute to more effective knowledge acquisition and skill development.

In the context of mathematics education, AI-supported instructional interventions have demonstrated promising results in enhancing students' mathematical understanding and performance. Adaptive learning systems can provide individualized problem sets based on students' learning progress, thereby ensuring that learning activities remain appropriately challenging and meaningful (Kulik & Fletcher, 2016). Such personalized support is particularly important for developing mathematical problem-solving skills, which often require sustained practice and guided reflection.

Research has also suggested that AI-based learning environments can encourage students to develop metacognitive skills during mathematical problem-solving. Through immediate feedback and interactive guidance, students become more aware of their thinking processes and are better able to monitor, evaluate, and adjust their solution strategies (Aleven et al., 2016). Metacognitive awareness is widely recognized as a critical factor influencing successful problem-solving performance.

Furthermore, AI-assisted learning can provide opportunities for collaborative and inquiry-based learning experiences. By facilitating access to diverse information sources and supporting interactive discussions, AI technologies can help students construct knowledge more actively and meaningfully (Kohnke et al., 2023). These characteristics are consistent with constructivist learning theories, which emphasize the active role of learners in building understanding through experience and interaction.

Although the educational potential of artificial intelligence has received increasing attention, research focusing specifically on elementary school students remains relatively limited. Much of the existing literature has concentrated on higher education, secondary education, or adult learning contexts (Zawacki-Richter et al., 2019). Consequently, empirical evidence regarding the effectiveness of AI-assisted learning for younger learners, particularly in elementary mathematics education, remains insufficient.

The limited availability of studies involving elementary school students creates an important research gap. Young learners possess unique cognitive, emotional, and developmental characteristics that may influence how they interact with AI-supported learning environments. Therefore, findings obtained from older student populations cannot automatically be generalized to elementary school contexts. Additional research is necessary to determine whether AI-assisted learning can effectively support mathematical problem-solving development among younger students.

Another gap in the literature concerns the measurement of learning outcomes. Existing studies frequently focus on academic achievement, learning motivation, or technology acceptance, while relatively few investigations specifically examine mathematical problem-solving ability as a primary outcome variable (Chen et al., 2020; Ouyang et al., 2022). Given the central role of problem-solving in mathematics education, further research is needed to understand how AI-assisted learning influences this critical competency.

The present study was conducted in response to these theoretical and empirical gaps. Preliminary observations in elementary school mathematics classrooms indicated that many students experienced difficulties in understanding mathematical problems, selecting appropriate solution strategies, and communicating their reasoning processes. These challenges were reflected in low levels of problem-solving performance and inconsistent achievement across students. Such conditions underscore the need for innovative instructional approaches capable of supporting more effective learning experiences.

Artificial intelligence-assisted learning was selected as an intervention because of its capacity to provide adaptive support, personalized feedback, and interactive learning opportunities. Through these features, AI technologies may help students engage more deeply with mathematical problems and develop stronger analytical reasoning skills. Moreover, AI-assisted learning aligns with current educational trends that emphasize digital transformation and technology-enhanced instruction in primary education.

This study contributes to the growing body of literature on artificial intelligence in education by providing empirical evidence from an elementary school context. Specifically, the study examines whether AI-assisted learning can significantly improve students' mathematical problem-solving ability compared with conventional learning approaches. The findings are expected to enrich theoretical discussions regarding AI integration in mathematics education while also offering practical implications for teachers, school administrators, and educational policymakers seeking to improve mathematics learning outcomes.

Based on the preceding discussion, the primary objective of this study is to investigate the effectiveness of artificial intelligence-assisted learning in improving elementary school students' mathematical problem-solving ability. The study seeks to provide evidence regarding the extent to which AI-supported instruction can enhance learning outcomes and serve as an alternative instructional strategy for addressing persistent challenges in elementary mathematics education.

METHODS

Research Design

This study employed a quantitative approach with an experimental research type to examine the effect of artificial intelligence-assisted learning on elementary school students' mathematical problem-solving ability. The research design used was quasi-experimental with a nonequivalent control group design. This design was chosen because it allows the researcher to compare experimental and control groups without the need for random assignment at the individual level, which is often difficult to implement in real classroom settings (Campbell & Stanley, 2015; Shadish, Cook, & Campbell, 2002). The design pattern is presented in Figure 1.

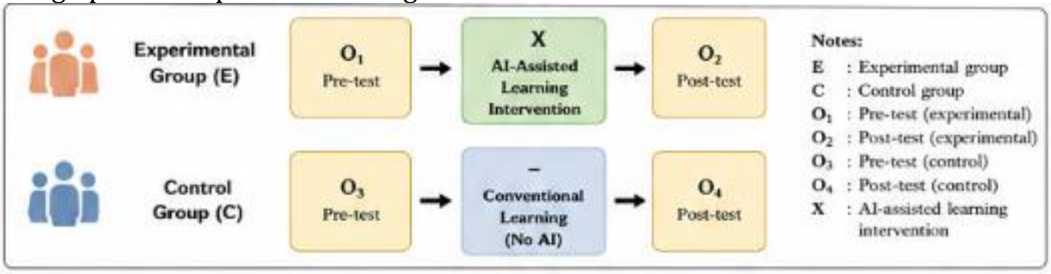

Figure 1. Quasi-experimental (Nonequivalent Control Group Design)

As illustrated in Figure 1, both groups were given a pre-test to measure the initial level of mathematical problem-solving ability. The experimental group then received instruction using AI-assisted learning, while the control group received conventional instruction without the integration of AI tools. After the intervention period, both groups were given an equivalent post-test to determine the changes in students' mathematical problem-solving ability.

Research Setting and Participants

This study was conducted in two public elementary schools in the Banyumas Regency, Central Java, Indonesia. The selection of schools was based on similarities in school accreditation, teacher qualifications, learning environments, and students' demographic backgrounds to ensure comparability between the two groups (Creswell & Creswell, 2018). The research was carried out during the even semester of the 2023/2024 academic year.

The participants consisted of 60 fifth-grade students. A total of 30 students from Blokoang State Elementary School constituted the experimental group, while 30 students from Petaeina State Elementary School constituted the control group. The intact classes in each school were assigned as research groups to maintain the natural classroom setting. Table 1 presents the demographic characteristics of the participants.

Table 1. Demographic Characteristics of Participants

Characteristic	Experimental Group (n=30)		Control Group (n=30)		Total (N=60)	
	f	%	f	%	f	%
Gender						
Male	16	53.33	15	50.00	31	51.67
Female	14	46.67	15	50.00	29	48.33
Age (years)						
10	12	40.00	13	43.33	25	41.67
11	15	50.00	14	46.67	29	48.33

12	3	10.00	3	10.00	6	10.00

Note. f = frequency; % = percentage

Research Variables and Operational Definition

The independent variable in this study is AI-assisted learning, while the dependent variable is students' mathematical problem-solving ability. The operational definition of the dependent variable refers to the ability of students to solve non-routine mathematical problems by applying Polya's (1957) four steps of problem-solving: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back (Polya, 1957; Schoenfeld, 1985). The indicators and descriptors are presented in Table 2.

Table 2. Indicators and Descriptors of Mathematical Problem-Solving Ability

Indicator	Description	Example of Student Behavior	Score Range
Understanding the problem	Ability to identify known information, conditions, and what is being asked in the problem.	Students can identify given data and write down what is known and what is asked.	0 - 5
Devising a plan	Ability to determine appropriate strategies or mathematical approaches to solve the problem.	Students can choose or design a relevant strategy (e.g., drawing, modeling, equation, algorithm).	0 - 5
Carrying out the plan	Ability to implement the chosen strategy systematically and accurately.	Students perform calculations or procedures correctly according to the planned strategy.	0 - 5
Looking back	Ability to check solutions and interpret the answer in the context of the problem.	Students verify the correctness of the solution and conclude appropriately.	0 - 5
Total Score (Maximum)			**0 - 20**

Research Instruments

The data were collected using a mathematical problem-solving ability test in the form of description items. The test was developed based on the indicators above and consisted of 5 non-routine problems aligned with the fifth-grade mathematics curriculum. The test instrument was validated by three experts in mathematics education to ensure content validity (Aiken's V > 0.80). A pilot test was conducted with 30 students from a school outside the research sample. The results of the item analysis are shown in Table 3.

Table 3. Item Analysis Results (Pilot Test)

Item	Difficulty Index (P)	Discrimination Index (D)	Reliability (Cronbach's α)

1	0.62	0.56	0.86
2	0.58	0.63	
3	0.55	0.60	
4	0.50	0.58	
5	0.61	0.64	

Note. $0.30 \leq P \leq 0.70$ (moderate difficulty); $D \geq 0.30$ (good); $\alpha \geq 0.70$ (reliable)

Learning Intervention

The experimental group received AI-assisted learning for 8 meetings (2 meetings a week, 2 x 35 minutes per meeting). The AI tools used provided automated tutoring systems that provided explanations, hints, examples, and immediate feedback. The intervention was conducted under the supervision of the main teacher who had been trained to use the tools. The control group received conventional learning. The learning objectives, content, and duration were identical but without the integration of AI tools.

Data Collection Procedure

The pre-test was administered to both groups one week before the intervention to measure initial problem-solving ability. After completing the learning intervention (8 meetings), the post-test was given to both groups using an equivalent test. Both tests were scored using an analytic rubric with a maximum score of 20.

Data Analysis Techniques

The data were analyzed using descriptive and inferential statistical techniques. Descriptive statistics were used to determine the mean, standard deviation, and percentage of mastery learning. Inferential statistics included prerequisite tests (normality and homogeneity) and hypothesis testing using independent t-test and paired t-test.

Descriptive Statistics

The descriptive measures were calculated using the following formulas:

Mean Score Formula:

$$X = \frac{\sum_{i=1}^{n} X_i}{n}$$

Standard Deviation Formula:

$$SD = \sqrt{\frac{\sum_{i=1}^{n} (X_i - X)^2}{n-1}}$$

Percentage of Mastery Learning:

$$P(\%) = \frac{\text{Number of students mastery criterion}}{\text{Total number of students}} \times 100\%$$

Information:
$\bar{X}$ = mean score;
SD = standard deviation;

Xi = individual score;
n = number of students;
P = percentage of mastery learning.

Inferential Statistics

Independent Samples t-test

Used to compare the post-test scores between the experimental and control groups.

$$t = \frac{X_E - X_C}{\sqrt{\frac{S_E^2}{n_E} + \frac{S_C^2}{n_C}}}$$

Paired Samples t-test

Used to compare pre-test and post-test scores within each group.

$$t = \frac{D}{\frac{S_D}{\sqrt{n}}}$$

Information:
$\bar{X}E$, $\bar{X}C$ = mean scores of experimental and control groups;
SE^2, SC^2 = variances; nE, nC = number of students;
$\bar{D}$ = mean difference (post-test - pre-test);
SD = standard deviation of difference;
n = number of paired data.

Decision Rule

The significance level (α) used in this study was 0.05 (two-tailed test). If the p-value (Sig. 2-tailed) < 0.05, then H0 is rejected and H1 is accepted. The analysis was conducted using SPSS version 26.0.

RESULTS

Descriptive Statistics of Students' Mathematical Problem-Solving Ability

To determine the effectiveness of artificial intelligence-assisted learning on elementary school students' mathematical problem-solving ability, descriptive statistical analyses were conducted. The descriptive analysis focused on three primary indicators, namely the mean score, standard deviation, and percentage of learning mastery. These indicators were used to provide a comprehensive overview of students' learning outcomes after the implementation of the instructional intervention.

The mean score was utilized to determine the overall achievement level of students in each group. Meanwhile, the standard deviation was employed to assess the distribution and consistency of student performance within each group. The percentage of learning mastery was calculated to evaluate the proportion of students who achieved the predetermined minimum mastery criterion. Table 1 presents the descriptive statistical results of students' mathematical problem-solving ability in both the experimental and control groups.

Table 4. Descriptive Statistics of Mathematical Problem-Solving Ability

Statistic	Experimental Group (n=30)	Control Group (n=30)
Mean	92.16	69.13
Standard Deviation	4.28	11.76
Highest Score	100	88
Lowest Score	80	45

Statistic	Experimental Group (n=30)	Control Group (n=30)
Learning Mastery (%)	95.61	70.33

The results presented in Table 1 indicate a substantial difference between the experimental and control groups. Students who participated in artificial intelligence-assisted learning achieved an average score of 92.16, whereas students who received conventional instruction achieved an average score of only 69.13. This difference suggests that the integration of artificial intelligence into mathematics learning contributed positively to students' mathematical problem-solving performance.

The higher mean score obtained by the experimental group indicates that students exposed to AI-assisted learning demonstrated superior abilities in understanding mathematical problems, devising solution strategies, implementing procedures, and evaluating solutions. The findings imply that AI-supported instructional activities provided learning experiences that facilitated deeper mathematical understanding and more effective problem-solving processes.

Another important finding concerns the comparison of standard deviation values. The experimental group obtained a standard deviation of 4.28, while the control group recorded a substantially larger standard deviation of 11.76. This finding indicates that students in the experimental group exhibited more homogeneous performance compared with students in the control group.

The smaller standard deviation observed in the experimental group suggests that the majority of students benefited consistently from the intervention. The reduced variability implies that AI-assisted learning not only improved average achievement but also supported more equitable learning outcomes across students with different ability levels.

In contrast, the larger standard deviation found in the control group indicates greater variation in student achievement. Some students performed relatively well, while others experienced considerable difficulties in solving mathematical problems. Such variability may reflect the limitations of conventional instructional approaches in accommodating diverse student learning needs.

The percentage of learning mastery further confirms the superiority of the experimental treatment. The experimental group achieved a mastery percentage of 95.61%, whereas the control group achieved only 70.33%. This difference demonstrates that a substantially larger proportion of students in the AI-assisted learning environment successfully attained the expected learning outcomes.

The mastery percentage achieved by the experimental group indicates that nearly all students met the established learning objectives. This result highlights the effectiveness of artificial intelligence-assisted learning in supporting both high-achieving and low-achieving students during mathematics instruction.

The combined evidence from the mean score, standard deviation, and mastery percentage suggests that AI-assisted learning produced more effective and more consistent learning outcomes than conventional instruction. To provide a clearer understanding of students' progress during the intervention period, pre-test and post-test scores for both groups were also analyzed.

Table 5. Pre-Test and Post-Test Scores

Group	Pre-Test Mean	Post-Test Mean	Gain Score
Experimental	58.37	92.16	33.79
Control	57.83	69.13	11.30

Table 2 demonstrates that both groups experienced learning gains following instruction. However, the experimental group exhibited a substantially larger gain score compared with the control group. This finding indicates that AI-assisted learning generated greater improvements in mathematical problem-solving ability.

The relatively similar pre-test means suggest that both groups possessed comparable initial abilities before treatment. Therefore, differences observed in post-test performance can reasonably be attributed to the instructional intervention rather than pre-existing differences between groups. The gain score analysis further strengthens the conclusion that artificial intelligence-assisted learning provided a more powerful learning environment for developing students' mathematical problem-solving skills.

Prerequisite Testing

Before conducting hypothesis testing, prerequisite analyses were performed to determine whether the data satisfied the assumptions required for parametric statistical procedures.

Normality Test

The Shapiro-Wilk test was employed to evaluate data normality.

Table 6. Results of Normality Test

Group	Statistic	Sig.
Experimental Pre-Test	0.964	0.351
Experimental Post-Test	0.958	0.246
Control Pre-Test	0.971	0.483
Control Post-Test	0.951	0.189

The results indicate that all significance values exceeded 0.05. Consequently, the data can be considered normally distributed.

The normal distribution of data suggests that students' scores were distributed symmetrically around the mean and did not exhibit extreme deviations that could compromise statistical analysis.

The fulfillment of the normality assumption provided a basis for proceeding with parametric hypothesis testing.

Homogeneity Test

Levene's test was conducted to examine the homogeneity of variances.

Table 7. Results of Homogeneity Test

Statistic	Sig.
Levene's Test	0.284

The significance value of 0.284 exceeds the alpha level of 0.05, indicating that the variances of both groups were homogeneous. The homogeneity finding implies that score variability was statistically comparable across groups. Therefore, the assumption of equal variances was satisfied. Because both normality and homogeneity assumptions were met, parametric statistical analyses were deemed appropriate.

Hypothesis Testing

Independent Samples t-Test

The independent samples t-test was performed to compare post-test scores between groups.

Table 8. Results of Independent Samples t-Test

Variable	t-value	Sig. (2-tailed)
Post-Test Scores	8.934	0.000

The significance value obtained was 0.000, which is smaller than 0.05. Therefore, the null hypothesis was rejected. This result indicates a statistically significant difference between students who learned through AI-assisted instruction and those who learned through conventional instruction. The magnitude of the observed difference suggests that the instructional treatment exerted a substantial impact on mathematical problem-solving ability.

Paired Samples t-Test

The paired samples t-test was conducted to determine whether significant improvements occurred within each group.

Table 9. Results of Paired Samples t-Test

Group	t-value	Sig. (2-tailed)
Experimental	18.742	0.000
Control	4.615	0.000

The results indicate that both groups experienced statistically significant improvements from pre-test to post-test. However, the experimental group demonstrated a substantially larger t-value, indicating stronger learning gains compared with the control group. The findings collectively support the conclusion that artificial intelligence-assisted learning significantly improved students' mathematical problem-solving ability.

DISCUSSION

The present study aimed to investigate the effectiveness of artificial intelligence-assisted learning on elementary school students' mathematical problem-solving ability. The findings consistently demonstrate that students who participated in AI-assisted learning achieved significantly better outcomes than students who experienced conventional instruction.

One of the most prominent findings concerns the difference in mean scores between groups. Students in the experimental group achieved an average score of 92.16, whereas students in the control group achieved only 69.13. This substantial difference indicates that AI-assisted learning facilitated deeper engagement with mathematical concepts and problem-solving processes.

The superior performance of the experimental group may be explained by the adaptive characteristics of artificial intelligence technologies. AI systems are capable of providing individualized learning experiences that align with students' learning needs and cognitive levels (Holmes et al., 2022). Such personalization likely contributed to more effective knowledge construction among students.

The findings support previous studies reporting that AI-assisted learning can improve mathematics achievement and learning effectiveness (Hwang & Tu, 2021; Chen et al., 2020). By providing immediate feedback and adaptive support, AI tools enable students to correct misconceptions and refine their problem-solving strategies in real time.

Another important finding relates to the smaller standard deviation observed in the experimental group. The lower variability indicates that learning outcomes were more evenly distributed among students.

This finding suggests that AI-assisted learning may contribute to educational equity by reducing achievement gaps within the classroom. Adaptive learning systems can provide differentiated support according to students' individual learning needs, thereby helping lower-achieving students improve their performance (Zawacki-Richter et al., 2019).

The mastery learning analysis further reinforces the effectiveness of AI-assisted learning. The experimental group achieved a mastery percentage of 95.61%, indicating that nearly all students reached the expected learning standards. High mastery rates are particularly important in elementary education because foundational mathematical competencies influence subsequent learning success. Students who develop strong problem-solving skills at an early age are more likely to demonstrate sustained achievement throughout their educational trajectories (Cai et al., 2022).

The significant improvement observed in the experimental group is consistent with constructivist learning theory. According to constructivist perspectives, learning occurs most effectively when students actively construct knowledge through interaction and exploration (Vygotsky, 1978). Artificial intelligence-assisted learning environments support such active engagement by encouraging students to explore alternative solution strategies and reflect on their reasoning processes.

The substantial gain score achieved by the experimental group indicates that students experienced meaningful conceptual growth during the intervention period.

This finding aligns with the work of Kulik and Fletcher (2016), who reported that intelligent tutoring systems can significantly enhance student learning outcomes through personalized instruction and continuous feedback. The significant paired-samples t-test results demonstrate that students' mathematical problem-solving abilities improved after exposure to AI-assisted learning.

Improvement in problem-solving ability may have occurred because AI tools facilitated all stages of Polya's problem-solving framework, including understanding problems, planning solutions, implementing strategies, and evaluating outcomes (Polya, 1957). The independent-samples t-test further confirmed that the observed differences were statistically significant. The significance of these findings extends beyond statistical considerations. From an educational perspective, the results indicate that artificial intelligence can serve as a practical instructional resource capable of enhancing mathematics learning in elementary schools.

The findings also support contemporary theories emphasizing the importance of technology-enhanced learning environments. Educational technologies that provide personalized guidance and immediate feedback have been shown to improve student engagement and achievement (Bond et al., 2024). AI-assisted learning appears particularly effective because it combines personalization, adaptability, and interactive feedback within a single learning environment.

Another noteworthy aspect concerns students' increased opportunities for independent learning. AI systems encourage students to explore solutions autonomously while still receiving guidance when needed. Such learning experiences promote self-regulated learning behaviors, which are strongly associated with academic success (Ouyang et al., 2022).

The findings further suggest that AI-assisted learning may strengthen students' metacognitive awareness. Through continuous feedback mechanisms, students become more conscious of their thinking processes and learning strategies. Enhanced metacognition is known to support effective problem-solving because students can monitor and regulate their cognitive activities more efficiently (Aleven et al., 2016). The study also contributes to the growing literature on artificial intelligence in primary education. While many previous investigations have focused on secondary or higher education settings, the present findings demonstrate that elementary school students can also benefit significantly from AI-supported instruction.

These results provide empirical evidence that artificial intelligence technologies can be successfully integrated into elementary mathematics classrooms. From a practical perspective, teachers may consider incorporating AI-based learning tools to complement conventional instructional practices. Such integration may help address persistent challenges related to mathematical problem-solving achievement.

School administrators and policymakers may also view AI-assisted learning as a promising strategy for supporting educational innovation and improving learning quality. Nevertheless, several limitations should be acknowledged. The study involved a relatively small sample and was conducted in a limited geographical context. Future studies should involve larger and more diverse populations to enhance generalizability. Future research may also investigate the long-term effects of AI-assisted learning, explore different AI technologies, and examine additional outcomes such as mathematical reasoning, creativity, motivation, and self-regulated learning.

The findings provide strong evidence that artificial intelligence-assisted learning represents an effective instructional approach for improving elementary school students' mathematical problem-solving ability. The results highlight the transformative potential of artificial intelligence in supporting more personalized, engaging, and effective mathematics learning experiences in elementary education.

CONCLUSION

This study concludes that artificial intelligence-assisted learning has a positive and statistically significant effect on elementary school students' mathematical problem-solving ability. Students who participated in AI-assisted learning demonstrated higher average achievement, a more consistent distribution of learning outcomes, and a greater percentage of learning mastery than students who received conventional instruction. The results of the descriptive and inferential statistical analyses consistently indicate that the integration of artificial intelligence can support the development of mathematical problem-solving skills in elementary mathematics learning. These findings suggest that AI-assisted learning may serve as a promising instructional alternative for enhancing students' engagement with mathematical problem-solving tasks while supporting improved learning outcomes. Nevertheless, the findings should be interpreted within the context of the study's sample and setting, and further research involving larger and more diverse populations is recommended to strengthen the evidence base regarding the effectiveness of artificial intelligence in elementary education.

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