Integration of Artificial Intelligence in Mathematics Learning: An Effort to Improve Creative Thinking Abilities

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Abstract

The existence of artificial intelligence (AI) technology has experienced very rapid development recently. This phenomenon opens up opportunities to use AI in mathematics learning. This research aims to analyze the effect of using AI on creative mathematical thinking abilities. A total of fifth-grade elementary school students with an average age of 11 years were involved as samples for this research. They come from different classes but are still at the same school. The experimental class (n_1=31) was given treatment in the form of mathematics learning assisted by AI technology and the control class (n_2=31) was given conventional learning. Data on creative thinking abilities were collected through pretests and posttests in the form of validated essay questions. Data on students' creative thinking abilities was then analyzed using descriptive and inferential statistics. The results of this research indicate that using AI technology in mathematics learning can be an alternative technology to improve students' creative thinking abilities.

Keywords: Artificial intelligence, Creative thinking, Mathematics learning

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1. Introduction

Thinking creatively is one of the abilities that is needed in the 21st century. Competition between countries in many fields, such as economic, social, and health, requires developing and developed countries to prepare a generation capable of thinking creatively. Creativity has been identified as a major goal of education and is currently one of the 21st-century skills that must be supported in schools (Chan & Yuen, 2014; Suherman & Vidákovich, 2022). The future of human civilization depends on the creative abilities of young people and one of the most important things that can be done is to continue to foster creative habits in students at school (Richardson & Mishra, 2018).

Wang & Hou (2018) reveal that creativity refers to an individual's ability to use known information to produce new and unique products that have social value. This argument emphasizes that creativity is a cognitive process that does not stand alone but is a combination of abilities and other aspects. Suherman & Vidákovich (2022) say that individuals involved in creative thinking activities will use their minds to create a series of new thoughts from a collection of memories containing various ideas, descriptions, concepts, experiences, and knowledge. In other words, creative thinking is characterized by the creation of something new from ideas, descriptions, concepts, experiences, and knowledge.

Margaliot & Magid (2020) view creativity from an affective perspective where creative thinking is seen as a thinking activity that involves motivation, personal characteristics and emotions, the

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ability to solve problems, the use of imagination, and perseverance when facing uncertainty. This definition seems to be based on Guilford's division of creativity which consists of aspects of flexibility, fluency, novelty, analysis, reorganization, redefinition, synthesis, complexity, and elaboration (Guilford, 1967). The creative thinking components proposed by Gilford have become the main reference for several subsequent researchers to explain the concept of creative thinking abilities. Apart from that, another aspect was also developed by Torrance (1966) in the form of the Torrance Tests of Creative Thinking (TTCT) which includes aspects of fluency, flexibility, elaboration, and originality to measure creative thinking abilities.

Currently, researchers have used many ways to develop creative thinking abilities. The psychodiagnostic approach is one way to develop creative thinking abilities (Oschepkov et al., 2022). Apart from that, several methods are also believed to be able to develop creative thinking skills, such as problem-posing learning (Wilkie, 2024), discovery learning (Nu'man, 2020), and the application of blended learning based on STEM or Science, Technology, Engineering, Art, Mathematics (Putri et al., 2023).

Even though research related to creative thinking has been carried out by many experts, students' creative thinking abilities have been in the spotlight in many countries and have subsequently been integrated into educational policy documents and curricula such as in Indonesia, Malaysia, Singapore, Nigeria, America, Australia and several developed countries. Others (Akbar et al., 2023; Christopher et al., 2020; Wilkie, 2024). Teachers still have to work hard to improve creative thinking abilities because students' creative thinking abilities in some schools are still low. For example, in Enugu state in Nigeria, Christopher et al. (2020) reported that students' creative thinking abilities are still very low. A similar condition also occurs in Indonesia where students' creative thinking abilities in Indonesia are still very low in solving mathematical problems (Akmam et al., 2024; Mentari et al., 2020).

In recent years, technological progress has experienced very rapid development and one of the technologies that is widely used is artificial intelligence (Mohamed et al., 2022). AI can personalize learning, by analyzing learning styles, levels of understanding, and student needs, thereby enabling an adaptive approach according to individual abilities (Holmes et al., 2019; Opesemowo & Adewuyi, 2024). Additionally, AI improves assessment efficiency with automation features, such as proofreading assignments and exams, and providing instant feedback, which helps students recognize their strengths and weaknesses while reducing the administrative burden on teachers (Li, 2024; Owan et al., 2023). AI also supports individual learning, acting as a virtual assistant that helps students understand difficult concepts, provides additional assignments, and guides the learning process more effectively (Rahadiantino, 2022). On the other hand, this technology encourages the development of critical thinking skills through AI-based tasks and challenges that are relevant to the needs of the modern world (Holmes et al., 2019). Furthermore, web-based AI platforms such as Duolingo and Khan Academy enable students around the world to access quality education without geographic limitations (Li, 2024; Rahadiantino, 2022).

Today, AI has a significant role in mathematics learning, helping students understand concepts with an adaptive approach, personalization, and greater efficiency (Anand et al., 2023). For example, platforms such as DreamBox Learning and MATHia customize materials based on student needs, thereby supporting more optimal individualized learning (Farrokhnia et al., 2023). In addition, AI-based systems provide great advantages in analyzing student performance data, allowing teachers to identify areas that require more attention, such as mastery of certain concepts, through comprehensive learning data (Maulida et al., 2024). AI integration has also been shown to improve student's learning outcomes and problem-solving skills, making it an

effective and innovative educational tool (Al Husaeni et al., 2022; Judijanto et al., 2024).

In practice, AI can respond to individual learning needs by diagnosing specific challenges and tailoring instructional support, which in turn improves overall mathematics competency (Hwang & Tu, 2021). Tools such as AI-based tutoring systems have demonstrated a positive impact on students' problem-solving skills as well as educators' perceptions of the usefulness of AI in the classroom (Joksimovic et al., 2023). Although many studies have been conducted on the use of AI, the number of studies on the application of AI in mathematics learning is still very limited. Many previous researchers have postulated the use of AI to promote higher-level thinking abilities such as creative thinking abilities. This research aims to analyze the effect of AI integration on students' creative mathematical thinking abilities.

2. Method

This research is intended to analyze the impact of implementing AI technology in mathematics learning in elementary schools. For this purpose, 62 fifth-grade elementary school students were involved in this research. They are an average of 11 years old and come from two different classes but at the same school. The first class consisting of 31 students was designated as the experimental class and the second class consisting of 31 students was designated as the control class. Intervention in the form of learning using AI technology was given to the experimental class and conventional learning was given to students in the control class. The experimental class and control class were given five lessons on the subject of the surface area of cubes and blocks and the volume of cubes and blocks. To obtain data on creative thinking abilities, students in the experimental class and control class were each given 5 creative thinking ability tests in the form of essay tests which had been empirically validated and considered by three mathematics education experts. The test was given twice, namely a test before intervention or pretest and a post-intervention test or post-test. The scoring criteria for the mathematical creative thinking ability test are prepared by adapting the mathematical creative thinking ability scoring rubric that has been developed Bosch (1997) as follows.

Table 1. Guide to Scoring Creative Thinking Abilities

Indicator	Student response	Score
Originality	Don't answer or give a wrong answer	0
	Write the answer but it is difficult/not understood	1
	Writing answers, a directed calculation process but incomplete or inaccurate	2
	Providing solutions with certain strategies, but inaccurate or wrong in the calculation process	3
	The calculation process and results are correct	4
Fluency	Doesn't answer or doesn't provide ideas that are relevant to the problem	0
	Produce solutions that are relevant to the given problem but are less clear in writing	1
	Provide solutions that are relevant to the given problem and are clear and complete in writing	2
	The solution given is more than one, relevant to the given problem, but the writing is not clear	3
	Produce more than one solution that is relevant to solving the problem and write it quite clearly and completely	4
Flexibility	Does not produce a solution or produces a solution in one or more ways, but is all wrong	0
	Producing solutions in one way but there are inaccuracies in the calculation process and production of wrong solutions	1
	Providing solutions in one strategy, precise calculation process, precise solution	2
	Provides more than one solution/strategy, but there is a description of the wrong answer due to inaccuracies when carrying out calculations	3
	Generate solutions for more than one strategy with the correct calculation and	4

	output process solution	
Elaboration	Not coming up with a solution or coming up with the wrong solution	0
	There is imprecision in developing a strategy without being detailed	1
	There is imprecision in developing the strategy, and it is accompanied by a lack of detail	2
	Develop strategies accurately and precisely with completion steps that are not complete	3
	Develop strategies accurately and completely	4

3. Results

The results of the data analysis show that the experimental class that used learning assisted by artificial intelligence (AI) technology experienced more significant improvements compared to the control class that used regular learning. The average pre-test score for the experimental class was 69,22 and after learning it increased to 79,43, with an N-gain of 0,35. This indicates that learning with the help of AI technology has a positive impact on improving students' abilities. In contrast, the control class that used conventional learning methods showed smaller improvements. The average pre-test score for the control class was 68.01, which then increased to 74.73 in the post-test, with an N-gain of 0,21. Even though there is an improvement, this lower N-gain shows that traditional learning does not have as big an impact as learning based on AI technology.

Table 2. Results of pre-test and post-test descriptive data analysis

Group	Mean pretest	Mean Post-test	N-gain
Experiment	69,22	79,43	0,35
Control	68,01	74,73	0,21

The greater increase in the experimental class shows that AI technology is effective in supporting the learning process and providing opportunities for students to develop creative thinking abilities. AI technology-assisted learning allows students to be more active and involved in learning, which in turn increases their understanding of the material being taught. Thus, learning assisted by AI technology is proven to be more effective than ordinary learning in improving student learning outcomes. Next, the critical thinking ability pretest data normality test was carried out using the Shapiro-Wilk test with the help of SPSS software. If the significance value (sig.) is greater than 0.05 then the data is said to have a normal Ho distribution. The homogeneity test was carried out using the Levene Test. The criterion for the homogeneity test is that if the significance value (sig.) is greater than 0.05 then the data has a homogeneous variance.

Table 3. Normality and Homogeneity Test of Critical Thinking Ability Pretest Data

Group	n	$\bar{x}$	s	Sig. (Shapiro-Wilk)	Sig. (Levene statistic)
Experiment	31	69,22	12,89	0,090	0,106
Control	31	68,01	6,75	0,083	

The results of the normality test using Shapiro-Wilk (SW) show that the data for both classes, experimental and control, follow a normal distribution. In the experimental class, the SW statistic is 0.94 with a significance value of 0.090, which is greater than 0.05, so it can be concluded that the data in the experimental class is normally distributed. The same thing applies to the control class, where the SW statistic is 0.94 with a significance value of 0.083, also greater than 0.05, which shows that the control class data is also normally distributed. Therefore, both classes meet

the assumption of normality, which allows the use of parametric statistical analysis to evaluate the differences between the groups and analyze the effect of the learning applied to the two groups.

Table 4. Independent sample test on Pretest Data

	t	df	Sig. (2-tailed)	Mean difference
t-test for equality of means	0,463	60	0,645	1,210

Next, the average difference test in the pretest data was carried out using the independent sample t-test. The testing criteria for the t-test are if the significance value is more than 0,05, then the ability to think creatively between the experimental class and the control class does not have a significant difference. The independent t-test shows that the significance value of 0,645 is greater than 0,05. Thus, it can be concluded that the initial scores of students from the two groups are comparable.

Table 5. Data Normality and Homogeneity Test
Post-test Creative Thinking Ability

Group	$\bar{x}$	s	Sig. (Shapiro-Wilk)	Sig. (Levene statistic)
Experiment	74,73	7,90	0,094	0,203
Control	79,43	10,31	0,543	

Table 6. Independent sample test on post-test data

	t	df	Sig. (2-tailed)	Mean difference
t-test for equality of means	2,01	60	0,048	4,70

The results of the normality test of the post-test data for creative thinking abilities showed that the significance value in the experimental class was 0.094 > 0.05, so it was concluded that the post-test data for creative thinking abilities in the experimental class had a normal data distribution. Likewise in the control class, which has a significance value of 0.543 > 0.05 it is concluded that the post-test data on creative thinking abilities in the control class has a normal data distribution. Next, the Levene Statistics homogeneity test was used to test the homogeneity of variance of the post-test data on creative thinking abilities between the experimental and control classes. The significance value shows 0.203 > 0.05 so it can be concluded that the post-test data on creative thinking abilities between the experimental and control classes has a homogeneous variance. Meanwhile, the post-test average difference test via the independent sample t-test showed a significance value of 0.048 <0.05. This shows that there is a significant difference between the creative thinking abilities of students in the experimental class and the control class. This also provides information that the scores of students who receive AI-assisted mathematics learning are better than students who do not receive AI-assisted learning.

4. Discussion

The results of this research show that the integration of AI in mathematics learning can improve students' creative thinking abilities. The results of this research show that learning assisted by artificial intelligence (AI) technology can significantly improve students' creative thinking abilities. This is in line with previous research showing the benefits of technology in

education. For example, Anand et al. (2023) found that the application of AI in mathematics learning was able to facilitate students' creative thinking processes through enriching interactive learning contexts. Another study by Moral-Sánchez et al. (2023) confirms that AI not only improves learning efficiency but also strengthens students' ability to explore creative solutions in problem-solving. This study also supports research results Toma and Yánez-Pérez (2024), which show that the use of AI can improve students' creative thinking skills by providing direct feedback during the learning process.

The results of this research support a number of previous studies which highlight the positive impact of technology on creative thinking abilities. For example, Wardat et al. (2023) suggest that AI can improve mathematical abilities and academic achievement although it must be acknowledged that AI such as ChatGpt currently can still offer comprehensive instruction and assistance in the study of geometry. Additionally, a study by Hwang and Tu (2021) found that the use of an AI-based adaptive learning platform significantly improved students' creative thinking abilities by personalizing their learning experience.

Mathematical thinking skills are essential as they form the foundation for understanding concepts and principles in various fields of knowledge (Akbar et al., 2023; Pramasdyahsari et al., 2023). Mathematical thinking involves analytical skills, logical reasoning, and problem-solving abilities, which are critical for everyday life and professional environments (Hidajat, 2023). With mathematical thinking, students can identify patterns, make predictions, and construct well-structured arguments to solve complex problems. Additionally, these skills foster higher-order thinking abilities, such as evaluation and data-driven decision-making, which are crucial in today's digital age.

Creative thinking in mathematics offers numerous benefits for students, particularly in enhancing their flexibility and innovation when tackling problems (Adharini & Herman, 2021). With creative thinking, students can generate unique and unconventional solutions while exploring alternative approaches to understanding mathematical concepts. This not only deepens their comprehension but also boosts their confidence in addressing challenging tasks. Furthermore, creative thinking encourages students to perceive mathematics as a dynamic and relevant discipline, fostering greater motivation to learn and equipping them with adaptive skills for various situations

This research is also in line with the findings of Melchor et al. (2023) which state that AI enables more inclusive learning and stimulates the exploration of new ideas. Furthermore, research Mohamed et al. (2022) reveals that AI can create a learning environment that supports the development of creativity by providing various problem-solving scenarios. Apart from that, Toma and Yánez-Pérez (2024) have also proven that the proper use of AI can increase creative abilities. This research supports the view Yunianto et al. (2024) which highlights that AI provides opportunities for students to enrich their mathematics learning experience so that it will improve high-level thinking skills.

The integration of AI with discovery learning approaches, as carried out in this research, shows positive synergy in improving students' academic achievements such as creative thinking abilities (Zheng et al., 2023). This is possible because the use of AI in learning can provide real-time feedback, and curriculum development, and empower educators. Egara and Mosimege (2024) also stated that AI can have an impact on increasing teaching effectiveness, increasing student engagement, and increasing understanding of complex concepts.

5. Conclusion

This research shows that the integration of artificial intelligence (AI) in mathematics learning significantly improves students' creative thinking abilities. These findings are in line with various previous studies that highlight the benefits of AI in supporting interactive, inclusive, and adaptive learning. AI is proven to be able to facilitate the exploration of creative solutions through real-time feedback, enriching learning contexts, and personalizing learning experiences. This research also supports the view that AI can create a learning environment that encourages the development of higher-order thinking skills, such as the ability to think creatively. By integrating AI into learning approaches such as discovery learning, this research confirms the existence of positive synergies in improving students' academic achievements, especially in creative thinking abilities.

However, this study has several limitations that need to be noted. First, this research focuses on the application of AI in mathematics learning, so the results may not be completely generalizable to other learning areas. Second, this research is limited to the use of certain AI technologies, so it has not explored various types or other AI platforms that may have different approaches to supporting learning. Third, although the positive impact of AI on creative thinking abilities has been proven, its influence on other dimensions, such as students' learning motivation or social skills, still requires further research.

Future research could broaden the scope by examining the effectiveness of AI in various disciplines and learning contexts. Additionally, it is important to explore how AI can be combined with other pedagogical approaches, such as project-based learning or collaboration between students, to holistically support the development of 21st-century skills. Future research could also focus on developing more inclusive and adaptive AI platforms, as well as evaluating their impact on different groups of students with different backgrounds.

6. Declarations

6.1. Data Availability Statement

The data presented in this study are available upon request from the corresponding author.

6.2. Conflicts of Interest

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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