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Artificial intelligence–supported deep learning approaches for enhancing mathematical literacy in elementary teacher education

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Abstract

The low level of mathematical literacy in Indonesia, particularly among PGSD students, highlights an urgent need to strengthen basic education competencies, prompting this study to examine the influence of deep learning supported by Artificial Intelligence (AI) on the mathematical literacy of PGSD students at Sultan Agung Islamic University (Unissula). Using a quasi-experimental One Group Pretest-Posttest design with 20 participants, the study implemented AI-assisted deep learning activities to enhance students' conceptual understanding and problem-solving skills. The results showed a significant improvement in mathematical literacy, indicated by a significance value of 0.000 between pretest and posttest scores, demonstrating the effectiveness of the instructional approach. Furthermore, the average student response score of 83.375 reflected strong engagement and a positive learning experience throughout the intervention. These findings suggest that integrating AI-supported deep learning can be a promising pedagogical strategy for improving mathematical literacy in PGSD programs and may contribute to the development of more adaptive, innovative, and technology-responsive learning environments in higher education.

INTRODUCTION

Background of the Study

In the era of the Industrial Revolution 4.0 and the transition toward Society 5.0, artificial intelligence (AI) has increasingly become an integral part of human life, including the field of education. AI introduces new possibilities in teaching and

learning processes, such as material personalisation, learning data analysis, and interactive concept modelling. The integration of AI also supports deep learning, which encourages not only memorisation but also deep conceptual understanding, reflection, and the application of knowledge in real-world contexts (Su & Bei, 2025).

Mathematical literacy is one of the essential competencies required of prospective elementary school teachers. It involves not only performing calculations but also the ability to use mathematical functions in daily life, solve problems, and make decisions based on data and numerical evidence. However, Indonesia's mathematical literacy level, as reflected in international assessments such as PISA, remains low and poses a serious challenge for future educators who will be responsible for improving the quality of basic education (Megawati & Sutarto, 2021).

Students in the Elementary School Teacher Education Program (PGSD) at Sultan Agung Islamic University (Unissula) are expected to understand and teach mathematical concepts contextually and meaningfully. Yet, initial observations and academic findings indicate that students still struggle to apply mathematical literacy functionally. Traditional learning approaches that are teacher-centred and the limited use of technology-based or AI-assisted learning contribute to this gap (Wahyuni et al., 2024).

AI-supported deep learning offers significant potential to address these issues. This learning approach requires students' active engagement, critical thinking, and conceptual understanding (Diputera, 2024). With AI assistance, learning can be personalised to students' levels of understanding and can provide immediate, accurate feedback. Thus, integrating AI and deep learning is expected to enhance students' conceptual mastery and support the development of reflective and contextual mathematical literacy essential for future elementary school teachers.

National statistics reinforce the urgency of this issue. PISA 2018 reported that Indonesia's mathematical literacy score was only 379, significantly below the OECD average of 489 (Özer, 2020). The 2021 National Assessment (AN) further shows that most Indonesian students demonstrate numeracy skills below the minimum level. These conditions highlight the need for innovative learning approaches that promote conceptual understanding, higher-order thinking, and meaningful learning experiences.

The Problem of The Study

The central problem addressed in this research is that PGSD Unissula students' mathematical literacy remains predominantly procedural and has not yet

reached the level of deep conceptual understanding. Existing learning practices do not fully facilitate higher-order thinking nor maximise the use of AI-based technology. As a result, current learning environments do not adequately support adaptive, meaningful, and technology-integrated learning (Kurniawan et al., 2025). Furthermore, informal interviews with PGSD students reveal that many still rely on memorising formulas without understanding the reasoning behind them. When confronted with contextual or reasoning-based problems, students often face confusion. Most students are also unfamiliar with AI-based platforms that could enhance their comprehension and problem-solving skills. These conditions underscore the need to examine whether integrating AI within deep learning can significantly improve PGSD students' mathematical literacy (Lestari et al., 2025).

Research's State of the Art

Several previous studies support the potential of AI in enhancing learning outcomes. Technology-based deep learning fosters active engagement and increases students' interest and performance in mathematics (Muhammad Haris Diponegoro et al., 2021). Additionally, findings by Nizaruddin & Kusmaryono on the five components of pseudo thinking are highly relevant, as these components can be detected and corrected through AI-assisted deep learning. AI can provide digital scaffolding that helps students identify reasoning errors and develop stronger mathematical literacy (Nizaruddin & Kusmaryono, 2023). While prior studies have explored AI in education and deep learning independently, research combining both approaches specifically for improving mathematical literacy in teacher education programs, especially in the Indonesian LPTK context, is still very limited (Novita et al., 2022).

Novelty, Research Gap, & Objective

This study introduces the systematic integration of AI technology within a deep learning framework specifically designed for mathematics learning in the elementary teacher education context. Such integration is still rarely implemented in Indonesian higher education institutions, particularly in PGSD programs. The research not only evaluates cognitive learning outcomes but also analyses improvements in mathematical literacy comprehensively, including problem solving, data interpretation, and reflective reasoning based on real-life contexts (Malik & B, 2025).

Although previous studies highlight the benefits of AI and deep learning separately, few have combined these two approaches to address the mathematical literacy challenges of prospective elementary school teachers (Zhai et al., 2024). Additionally, studies focusing specifically on PGSD students' literacy development-an

essential foundation for their future teaching roles-remain limited. This unexplored area forms the gap that this research aims to fill.

The objective of this study is to examine the significant effect of AI-based deep learning on improving the mathematical literacy of PGSD Unissula students. The study aims to contribute both theoretically and practically to the development of technology-integrated learning models for future elementary school teachers. Furthermore, it seeks to provide insights for policymakers and educators in designing more effective, adaptive, and relevant mathematics curricula aligned with the needs of the digital era (Saputra et al., 2025).

METHOD

Type and Design

This study employed a quantitative approach using a quasi-experimental research design with a One Group Pretest–Posttest Design (Nizaruddin & Kusmaryono, 2023). In this design, a single group of participants receives a pretest, followed by a treatment, and then a posttest without the use of a control group. The procedure included administering a pretest to measure students' initial mathematical literacy, providing treatment in the form of deep learning instruction assisted by artificial intelligence (AI), and conducting a posttest to examine changes in students' performance after the intervention. The research subjects consisted of 20 students from the Elementary School Teacher Education Program (PGSD) at Sultan Agung Islamic University (Unissula), selected through purposive sampling based on availability and active participation in mathematics courses.

Data and Data Sources

Two main data sources were used in this study: (1) Mathematical literacy test data obtained from pretest and posttest scores, and (2) Student response questionnaire data, collected after the learning intervention. The mathematical literacy test consisted of context-based multiple-choice questions designed to measure students' abilities in conceptual understanding, mathematical communication, data interpretation, and application of mathematics in real-life contexts.

Table 1 Test Grid

No.	Indicator	Question Statement/Description	Number of Questions
1	Understanding Mathematical Concepts	Identifying flat shapes resulting from combining two equilateral triangles	1
2		Combine two right triangles and one rectangle into a new shape.	2
3	Mathematical Communication	Determine the flat shape of the book's surface and calculate its area	1
4		Connecting real objects with mathematical concepts	1
5	Data Analysis and Interpretation	Determine the number of small plane shapes (squares and triangles) that cover a certain surface.	1
6		Analysing the efficiency of using flat shapes to cover a plane	2
7	Application of Mathematics in Life	Identifying flat shapes from house plans	1
8		Calculating the perimeter of a flat shape on a house plan	1

The second source of data was a Likert-scale student response questionnaire measuring students' perceptions of the AI-assisted deep learning model in terms of involvement, interest, creativity, and learning enjoyment.

Table 2. Student Response Questionnaire Grid

Indicator	Question	Code
Active Involvement	I am actively involved in the learning process	a
	I feel that I have an important role in the learning process.	b
Interest and Enthusiasm	I feel enthusiastic and excited when studying	c

	I feel that the learning materials presented are interesting and challenging.	d
Creativity	I feel that I have the opportunity to express my creativity in the learning process.	e
	I can use my own ideas in the learning process.	f
A Fun Learning Experience	I feel that the learning process is a pleasant experience.	g
	I feel that I can enjoy the learning process without feeling stressed.	h

Data Collection Technique

Data were collected through a mathematical literacy test administered both before and after the intervention, and through a student response questionnaire distributed at the end of the learning process. The instruments were designed to capture cognitive improvement and students' perceptions of the AI-assisted deep learning model.

Data Analysis

The pretest and posttest results were analysed using a parametric statistical test, namely the paired sample t-test, to determine the effect of AI-assisted deep learning on students' mathematical literacy. Meanwhile, data obtained from the student response questionnaire were analysed descriptively and quantitatively to illustrate the degree of student acceptance and perceptions of the learning approach used.

RESULTS

The results of this study are presented to provide an overview of the influence of AI-assisted deep learning on the mathematical literacy of Unissula PGSD students. Data were obtained through pretest and posttest tests, as well as student response questionnaires, which were then analyzed quantitatively. The following are the pretest and posttest value data

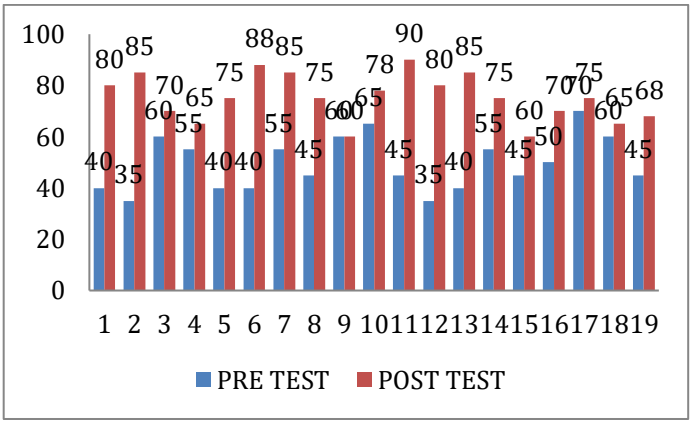

Figure 1. Recapitulation of Results of Pretest and Posttest Values

The image above is a bar graph showing the pre-test and post-test results of the mathematical literacy of Unissula PGSD students after participating in deep learning-based learning through Artificial Intelligence. The blue colour represents the pre-test score, while the red colour shows the post-test score of 19 students. It can be seen that all students experienced an increase in scores after participating in the learning, which indicates that the application of the deep learning method with AI support has an effect on students' understanding of mathematical literacy. Then, from the results of the pretest and posttest, the instrument test got the following results:

A validity test was conducted to evaluate 20 questions by comparing the R Calculation value to the R Table (0.36). The results showed that 10 questions were declared valid (questions 1, 7, 8, 9, 10, 11, 12, 17, 19, and 20) because the R Calculation was greater than R Table, while the other 10 questions (questions 2, 3, 4, 5, 6, 13, 14, 15, 16, and 18) were declared invalid because the R Calculation was less than or equal to R Table.

Table 3. Reliability Test Results

Reliability Test	
Reliability	Category
0.740	Tall

Reliability tests are conducted to measure the consistency and stability of measurement instruments. The test results showed a reliability value of 0.740, which is included in the high category. This means that the instrument has a good level of reliability in providing consistent results.

The discriminatory power test assessed the ability of each question to differentiate between high (A) and low (B) ability participants. The results showed

that question 1 had the highest discriminatory power (0.80) and was categorised as "Very Good." A total of 8 questions were categorised as "Good," 4 questions as "Fair," and 5 questions as "Poor," indicating that most of the questions were effective in differentiating the ability levels of participants.

The difficulty level measures the level of difficulty of each question in the exam. From the analysis results, only 3 questions are categorised as "Moderate" (questions 1, 10, and 19) with difficulty values of 0.40, 0.27, and 0.27, respectively. Meanwhile, the other 17 questions are categorised as "Difficult," indicating that most of the questions have a high level of difficulty. This shows the need for adjustments in the preparation of questions to make them more balanced.

An initial data normality test was conducted using the Kolmogorov-Smirnov and Shapiro-Wilk methods. The test results showed a significance value (Sig.) for Shapiro-Wilk of 0.128, which is greater than 0.05. This indicates that the data is normally distributed. In contrast, the Sig. The value for Kolmogorov-Smirnov is 0.036, which indicates that the data is not normally distributed. However, since the Shapiro-Wilk results are more reliable for small samples, it can be concluded that the data can be considered normal based on the Shapiro-Wilk test.

	Kolmogorov-Smirnov [a]			Shapiro Wilk		
	Statistics	Df	Sig.	Statistics	df	Sig.
Pre_Test	,180	25	,036	,937	25	**,128**

a. Lilliefors Significance Correction

Figure 2. Initial Data Normality Test Results

The final data normality test was conducted using the Kolmogorov-Smirnov and Shapiro-Wilk methods. The test results showed a significance value (Sig.) for Shapiro-Wilk of 0.284, which is greater than 0.05, indicating that the data is normally distributed. Meanwhile, the Sig. The value for Kolmogorov-Smirnov is 0.200, also indicating that the data does not deviate from the normal distribution. Thus, it can be concluded that the final data can be considered normal based on the results of the Shapiro-Wilk test.

The results of the Paired Sample T-Test showed a significance value (Sig. 2-tailed) of 0.000 (<0.05), which means there is a significant difference between the pre-test and post-test values. Thus, it can be concluded that Deep Learning through

Artificial Intelligence has a significant effect on improving the mathematical literacy of PGSD Unissula students.

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	T	df	Sig. (2-tailed)
Pair 1	Pre_Test - Post_Test	-25,640	14,911	2,982	-31,795	-19,485	-8,598	24	**,000**

Figure 3. Paired Sample t Test Results

After conducting a Paired Sample T-Test, which showed a significant influence, the following presents the questionnaire data on student responses to Deep Learning through Artificial Intelligence, which includes aspects of active involvement, interest and enthusiasm, creativity, and a pleasant learning experience.

Table 4. Student Responses to Deep Learning through Artificial Intelligence

No	Assessment Aspects	Total
1	Active Involvement (a)	78
2	Active Involvement (b)	81
3	Interest & Enthusiasm (c)	89
4	Interest & Enthusiasm (d)	85
5	Creativity (e)	82
6	Creativity (f)	77
7	Learning Experience (g)	91
8	Learning Experience (h)	84
	Total	667
	Number of Students	20
	Average Score per Student	83,375

Based on the data recapitulation, the total value of the eight assessment aspects reached 667, with an average of 83.375 from 20 students. The highest value was in the Learning Experience aspect (91), while the lowest value was in the Creativity aspect (f) (77).

DISCUSSIONS

This research was conducted through systematic steps, starting with the preparation of instruments in the form of pre-test, post-test, and student response questionnaires. In addition, the success of deep learning is also strongly influenced by the readiness of cyberlearning infrastructure, including system quality, information accessibility, and the digital competence of both teachers and students, as emphasized (Jupriyanto et al., 2025), who found that these factors are essential foundations for implementing effective and adaptive AI-assisted learning in elementary education. Learning was carried out using a deep learning approach assisted by Artificial Intelligence (AI), which emphasises the process of deep thinking, collaboration, real problem-solving, and reflection. After the learning intervention was completed, students took a post-test and filled out a questionnaire to measure their perceptions of the learning process that had been completed (Ustun et al., 2023).

The results of the Paired Sample T-Test showed a significance value of 0.000 (<0.05), indicating that there was a significant influence between the pre-test and post-test. This finding shows that deep learning has a real impact on students' mathematical literacy. This increase is an indicator that a constructivism-based approach that encourages active and reflective involvement has a positive impact on learning outcomes (Kurniawati et al., 2023).

Conceptually, deep learning provides space for students to understand the material in depth, not just memorise it. This approach encourages students to relate concepts to real-world contexts, discuss, and critically evaluate ideas. These results are in line with the theory, which emphasises that deep learning strengthens the integration between knowledge, understanding, and application (Jupriyanto et al., 2025).

The application of deep learning in this study not only emphasises deep conceptual understanding, but is also packaged through a joyful learning approach or fun learning. This concept aims to create a positive, interactive learning atmosphere and arouse students' curiosity. In implementing learning, lecturers combine deep learning strategies with various media such as concrete teaching aids, educational songs, and math-based play activities. This aims to stimulate students' cognitive and affective involvement in a balanced manner (Alhebaishi et al., 2025).

Joyful learning is a reinforcement of deep learning, because when the learning atmosphere is fun, students will be more open to absorbing knowledge, thinking creatively, and motivated to complete challenges independently or in groups

(Nurhakiki et al., 2024). For example, in geometry learning, students are invited to compose flat shapes from triangular and rectangular pieces of cake using visual aids. Math-themed songs are also used to strengthen memories of basic formulas and concepts, while educational games are used to spark exploration and collaboration (Huang, 2022).

This approach is in line with Vygotsky's theory, which emphasizes the importance of social interaction and tools in meaningful learning. When students are involved in playing and singing activities, they not only learn cognitively, but also socially and emotionally (Kusumadewi, et al., 2025). This full involvement strengthens the absorption of mathematical concepts, making learning not only effective but also memorable in terms of experience (Vale & Barbosa, 2023).

The questionnaire used consisted of eight indicators reflecting four main aspects, namely active involvement, interest and enthusiasm, creativity, and enjoyable learning experiences. The total overall score reached 667 from 20 students, with an average score of 83.375. Analysis per item shows that the enjoyable learning experience indicator obtained the highest score, namely 91 (a combination of items g and h). This reflects that students feel happy, emotionally involved, and do not feel burdened during the learning process. The interactive factors of AI media and the collaborative approach of deep learning are very likely to be the triggers for this positive experience (Bai & Wang, 2025).

The interest and enthusiasm aspects also showed high scores, namely 89 and 85. Students showed interest in the learning process that was not only one-way, but involved their active participation in building understanding through discussion activities and independent exploration (Ali & Hashmi, 2025). For active involvement, the scores were at 78 and 81, indicating that the majority of students were quite active in the learning process, although there was still room for improvement. Some students may need more motivation or an approach that suits their learning style. Meanwhile, the creativity aspect, especially in item f, recorded the lowest score, namely 77. This shows the need for innovation in designing learning activities that are more challenging and stimulate students' creativity, such as open-ended assignments, visual projects, or technology integration for digital flat design (Bereczki & Kárpáti, 2021).

The integration between deep learning and joyful learning has proven effective, as seen from the highest score achieved in the aspect of joyful learning experience (91), based on the results of the student response questionnaire (Ricita et

al., 2025). This means that a learning approach that combines depth of thinking and joy in the learning process can improve the quality of education. In other words, learning mathematics is no longer seen as rigid and difficult material, but as an enjoyable experience, building meaning, and fostering a spirit of continuous learning.

CONCLUSION

Deep learning supported by Artificial Intelligence (AI) shows a positive influence on the mathematical literacy of PGSD students at Sultan Agung Islamic University (Unissula). The results of the study indicate that this method significantly improved the understanding of mathematical concepts. In addition, students reported a more enjoyable and interactive learning experience, which encouraged active involvement in the learning process. Thus, the integration of technology in mathematics education not only improves learning outcomes but also prepares prospective teachers to face the challenges of education in the digital era.

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