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The Effectiveness of a Deep Learning Based Experiential Learning Model in Improving Mathematical Literacy

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ABSTRACT

This study aims to analyze the effectiveness of the deep learning-based experiential learning model in improving students' mathematical literacy skills compared to discovery learning. The study used a quantitative approach with a quasi-experimental design involving 120 students, consisting of 60 students in the experimental group and 60 students in the control group. Mathematics literacy ability data was obtained through pretest and posttest tests, then analyzed using normality tests, homogeneity tests, independent sample t-tests, and N-gain. The results showed that the average mathematical literacy ability of the experimental group increased from 43.87 in the pretest to 80.16 in the posttest, while the control group increased from 43.96 to 61.48. The results of the normality and homogeneity test showed that the data were normally distributed and had a homogeneous variance. The independent sample t-test showed a significant difference between the two groups with a value of $t = 12.004$ and $p < 0.001$. The results of the N-gain analysis showed an average increase in the experimental group of 0.6533 in the medium category, while the control group was 0.1164 in the low category. These findings show that deep learning-based experiential learning is more effective than discovery learning in improving students' mathematical literacy skills. This effectiveness is supported by the integration of learning experience, reflection, conceptual understanding, knowledge application, and the principles of mindful, meaningful, and joyful learning.

Keywords: Literacy, Deep Learning, Mathematical Literacy, Learning Model

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INTRODUCTION

The Mathematical literacy is one of the important skills needed by students to face various problems in daily life. Mathematical literacy is not only related to the ability to perform calculations correctly, but also includes the ability to understand problems, formulate situations mathematically, use relevant concepts and procedures, and interpret and evaluate results in the context of problems (Salsabila, 2024). Thus, mathematics learning needs to be directed at developing the ability to use mathematics as a tool for thinking and making decisions, not just memorizing formulas and procedures (Simbolon & Nurjanah, 2024). The problem of mathematical literacy is still a challenge in mathematics learning. The students are often able to solve problems that have a similar form to the example given by the teacher, but experience difficulties when facing different, contextual, or requires several stages of solution. This condition shows that procedural mastery is not always followed by the ability to transfer mathematical knowledge to a new situation (Simbolon & Nurjanah, 2024). The mathematics learning needs to provide students with greater opportunities to experience problems, construct knowledge, reflect, and reuse this knowledge in different situations (Yılmaz & Kesebir, 2023).

One of the relevant learning models to overcome these problems is experiential learning. Experiential learning places experience as an important part of the knowledge construction process. Through concrete experiences, students not only receive information from the teacher, but interact directly with the problems at hand. The experience is then reflected, associated with concepts, and reused in new situations (Yılmaz & Kesebir, 2023). Thus, experiential learning has the potential to support the mathematical thinking processes necessary in mathematical literacy. Previous research has shown that experiential learning can contribute to mathematics learning. Experiential learning allows students to connect mathematical concepts with more real and meaningful situations. The process of experience and reflection also provides an opportunity for students to understand the reasons behind the use of a mathematical procedure, rather than simply following the solution steps that have been given (Žakelj et al., 2024).

However, experiential learning can still be further developed so that the experiences provided to students truly produce deep learning. Concrete learning experiences do not automatically produce deep understanding if they are not accompanied by awareness of the learning process, meaning of experiences, and learning environments that encourage active involvement (Aulia et al., 2023). Therefore, experiential learning needs to be integrated with the principles of deep learning. In the context of this study, deep learning is understood as a pedagogical approach that emphasizes three main principles, namely mindful, meaningful, and joyful (Siregar et al., 2025a). Mindful learning encourages students to be aware of their thinking processes, strategies, and learning experiences. Meaningful learning helps students connect new knowledge with existing experiences and knowledge. Meanwhile, exhilarating learning creates a learning atmosphere that encourages engagement, exploration, collaboration, and courage in trying different problem-solving strategies (Siregar et al., 2025a).

Recent research further strengthens the importance of integrating deep learning in mathematics learning. Research by Hardianti et al (2025), for example, found that the integration of Problem-Based Learning with deep learning pedagogy has a significant influence on mathematics literacy. The experimental group obtained an average N-Gain of 0.57, while the control group only achieved 0.21. The findings suggest that the principles of deep learning can strengthen problem-oriented learning and mathematical literacy. Another research by Salma & Wijayanti (2025) also shows the development of the application of deep learning-based learning in mathematics education. One study developed a deep learning-based adaptive electronic module for mathematics learning and reported an increase in students' average scores from 57.97 in the pretest to 69.44 in the posttest. The findings show that learning designed with deep learning principles can provide a more contextual learning experience and support mathematical understanding. However, research that specifically integrates experiential learning with deep learning principles to improve mathematical literacy is still relatively limited. Some studies examine experiential learning as a learning model, while others examine deep learning through models such as Problem-Based Learning. The position of this research is to integrate the two perspectives into a single learning model that places experience, reflection, concept construction, and application as the core of learning, while the principles of awareness, meaning, and exhilaration are the characteristics that color each stage of learning (Wardono et al., 2025).

The integration has a strong relevance to the characteristics of mathematical literacy. In the process of concrete experience, students are faced with contextual problems that require the use of mathematics. In the process of reflection, students analyze information, strategies, and errors that arise. In the conceptualization process, students build or strengthen mathematical concepts. Furthermore, in the process of active experimentation, students apply the concepts obtained to new problems or contexts. Based on this description, this study aims to analyze the effectiveness of the experiential learning model based on deep learning in improving students' mathematical literacy. The research questions asked are: Is the experiential learning model based on deep learning effective in improving students' mathematical literacy?

METHOD

This study uses a quantitative approach with a quasi-experimental method. The research design used is a nonequivalent pretest-posttest control group design. This design was chosen because the research was conducted in the class that has been formed so that the researcher does not randomize individual students. The research design can be seen in Table 1.

Table 1. Research Design

Groups	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_3	C	O_4

Kterangan:

O_1 = pretest of the experiment group
O_2 = posttest of the experiment group
O_3 = pretest control group
O_4 = posttest control group
X = model experiential learning berbasis deep learning
C = model discovery learning

The research subject is grade VIII students at SMP N 1 Brangsong for the 2026/2027 school year. The number of research subjects is 120 students consisting of 60 students in the experimental group and 60 students in the control group. The selection of research subjects was carried out using random sampling techniques. Classes VIII A and VIII B as experimental groups were treated with a deep learning-based experiential learning model and classes VIII C and VIII D as the control group were treated with a discovery learning model. The main instrument in this study is the mathematics literacy test. The test was developed in the form of contextual description questions that measure students' ability to use mathematics to solve problems.

The instrument was validated by five validators who have expertise in mathematics education. Data analysis was carried out using descriptive and inferential statistics. Descriptive statistics were used to determine the average value, standard deviation, minimum value, and maximum value. Before hypothesis testing, the data was analyzed through normality and homogeneity tests. Next, a difference test was carried out to determine the difference in mathematical literacy ability between the experimental group and the control group. The improvement of mathematical literacy ability was also analyzed using N-Gain.

RESULT AND DISCUSSION

The results of the descriptive analysis of the mathematical literacy ability of the experimental group and the control group are presented in Table 2.

Table 2. Descriptive Statistics of Mathematical Literacy

Groups	N	Average Pretest Score	Average Posttest Score	Standard Deviation
Experiment	60	43,87	80,16	5,646
Control	60	43,96	61,48	6,204

Based on Table 2, the average mathematical literacy ability of the experimental group increased from 43.87 in the pretest to 80.16 in the posttest. Meanwhile, the average of the control group increased from 43.96 to 61.48. The results of the normality test can be seen in Table 3.

Table 3. Normality Test Results

Groups	Statistics	df	Sig.
Pretest Experiment	0,965	60	0,391
Posttest Experiment	0,957	60	0,244
Pretest Control	0,962	60	0,414
Posttest Control	0,964	60	0,125

Based on Table 3, it was found that the Kolmogorov-Smirnov normality test in the mathematical literacy test had a significant value of 0.391 in the pretest of the experimental group and 0.244 in the posttest of the experimental group while in the pretest of the control group a significant value of 0.414 and in the posttest The control group obtained a significant value of 0.125 so that the significant value in both experimental and control groups was greater than α. Based on the results of the analysis, it can be concluded that the two samples came from a normally distributed population, both the pretest and posttest of the experimental group and the pretest and posttest control groups. The results of the homogeneity test can be seen in Table 4.

Table 4. Homogeneity Test Results

	Levene Statistics	df1	df2	Sig.
Based on Mean	0,155	1	120	0,695
Based on Median	0,138	1	120	0,712
Based on Median and with adjusted df	0,138	1	117,134	0,712
Based on trimmed mean	0,157	1	120	0,693

Based on Table 4, the results of the Levene homogeneity test with a significant value of 0.695 were obtained so that the significant value was greater than α. Therefore, it can be concluded that the sample came from a homogeneous population. The results of the average difference test can be seen in Table 5.

Table 5. Average Difference Test Results

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LM	Equal variances assumed	12,004	120	0,000	18,680	1,556	15,563	21,797
	Equal variances not assumed	11,925	117,093	0,000	18,680	1,566	15,538	21,822

Based on Table 5, a significant value of 0.000 was obtained on equal variances assumed so that the significant value was less than equal to 0.05. This shows that the average completeness of students' mathematical literacy with deep learning-based experiential learning is more than the average completeness of students' mathematical literacy with discovery learning. The results of the improvement test can be seen in Table 6.

Table 6. Improvement Test Results

	Groups		Statistics	Std. Error
N-gain_Skor	Experiment	Mean	0,6533	1,17478
		Minimum	0,56	
		Maximum	0,78	
	Control	Mean	0,1164	4,38246
		Minimum	-0,28	
		Maximum	0,35	

Based on Table 6, it was found that the experimental group had a mean value of 0.6533 which indicates that the N-gain value was included in the medium category, while the control group had a mean of 0.1164 which indicates that the N-gain value was included in the low category. Based on Table 6, it can also be concluded that the average increase in mathematics

literacy of students with experiential learning based on deep learning is higher than the average increase in mathematics literacy of students with discovery learning.

The results showed that the application of the deep learning-based experiential learning model provided a higher increase in mathematical literacy skills compared to discovery learning. Based on descriptive analysis, the average mathematical literacy ability of the experimental group increased from 43.87 during the pretest to 80.16 during the posttest. Meanwhile, the control group that obtained discovery learning increased from an average of 43.96 to 61.48. The difference in improvement shows that learning that provides opportunities for students to experience, reflect, build understanding, and apply concepts directly is more able to support the development of mathematical literacy than learning that does not specifically integrate concrete experiences and deep reflection.

The improvement in both groups showed that both deep learning-based experiential learning and discovery learning both contributed to the development of mathematical literacy skills. However, a larger increase in the experimental group showed the superiority of the approach used. The average posttest of the experimental group reached 80.16, while the control group only reached 61.48. Thus, the average posttest difference of 18.68 points showed that students who participated in deep learning-based experiential learning had better mathematical literacy skills after receiving the treatment. These findings are in line with the research of Žakelj et al (2024) who found that the application of active learning and experiential learning in mathematics learning gave better results than the control group, especially in conceptual knowledge, simple problem solving, and complex problem solving.

The advantages of deep learning-based experiential learning can be explained by its learning characteristics that place student experience as the main source of knowledge formation. In mathematics learning, concrete experience allows students not only to accept the solution procedure, but also to understand the relationship between the problem faced and the relevant mathematical concept. This process is important in the development of mathematical literacy because mathematical literacy is not only related to the ability to do calculations, but also the ability to understand problems in context, formulate problems mathematically, use the right concepts or procedures, and interpret mathematical results in real-life contexts. Research by Mashuri et al (2023) shows that one of the difficulties students have in solving PISA-oriented problems is processing information and formulating problems systematically.

The application of deep learning principles further strengthens the process. In the context of this study, deep learning does not refer to artificial intelligence technology, but to a pedagogical approach that integrates the principles of mindful learning, meaningful learning, and joyful learning. These three principles allow the learning experience not to stop at doing activities, but to continue with awareness of the thinking process, meaning of concepts, and positive learning experiences. Siregar et al (2025b) explained that deep learning-based mathematics learning is directed at deep conceptual understanding, critical thinking, knowledge transfer to various contexts, and active student involvement through meaningful, mindful, and joyful learning.

The principle of meaningful learning plays an important role in explaining the improvement of the mathematical literacy skills of the experimental group. Through close experience with real-life situations, students have the opportunity to connect the mathematical knowledge they already have with the new problems they face. This relationship helps students understand that mathematical concepts are not just a collection of formulas, but a tool to understand and solve life problems. This is in line with the characteristics of mathematical literacy which requires the ability to use mathematics in various contexts. Research on the application of experiential learning in mathematics also shows that this approach can help students develop the ability to connect mathematical concepts with relevant situations and experiences. Research by Buakieow dan Kijkuakul (2023), for example, shows that experiential learning combined with mathematical tasks can be used to develop students' mathematical connection skills.

In addition to meaningful learning, the principle of mindful learning contributes to improving mathematical literacy through reflection activities. After gaining experience in

solving problems, students are directed to re-examine the thinking process, strategies used, mistakes made, and the reasons for choosing a procedure. The reflective process allows students to realize how they obtained a solution and whether the solution is in accordance with the context of the problem. Thus, reflection activities become a bridge between concrete experiences and the formation of conceptual understanding. Kurnianingsih et al (2026) emphasized that the integration of mindful, meaningful, and joyful learning makes learning not only oriented to understanding concepts, but also to reflection and the development of metacognitive abilities.

The principle of joyful learning also has a role in creating a learning atmosphere that encourages students to actively explore problems. A positive learning atmosphere can reduce students' tendency to simply wait for a solution procedure from the teacher. Instead, students are encouraged to try various strategies, discuss, express opinions, and evaluate alternative solutions. In mathematics literacy learning, this condition is very important because solving contextual problems often cannot be done with just one routine procedure. Research by Andayanie et al (2025) shows that the integration of mindful, meaningful, and joyful learning can increase student involvement, critical thinking, and intrinsic motivation, although its implementation requires teacher readiness and adjustment of the learning system.

The results of the normality test in this study showed that all pretest and posttest data in both the experimental group and the control group were distributed normally. The significance value of each data was 0.391; 0,244; 0,414; and 0.125, all of which are greater than 0.05. This condition indicates that the data meets the assumption of normality so that parametric analysis can be used to test the mean difference between the two groups. Furthermore, the results of the homogeneity test show a significance value of Levene of 0.695 which is greater than 0.05. Thus, the variance of the two groups can be declared homogeneous. The fulfillment of the assumptions of normality and homogeneity provides an adequate statistical basis to conduct an average difference test using an independent sample t-test.

The results of the mean difference test showed a t-value of 12.004 with df = 120 and a significance of 0.000 under the condition of equal variances assumed. In scientific reporting, the significance value of 0.000 should be written as $p < 0.001$, because the probability value is statistically not really zero. These results show a very significant difference between the mathematical literacy ability of students in the experimental group and the control group. The mean difference of 18,680 with a 95% confidence interval between 15,563 to 21,797 further strengthens that the difference is not just a small difference statistically. Thus, experiential learning based on deep learning provides significantly higher mathematical literacy results than discovery learning.

These findings reinforce the results of previous research on experiential learning in mathematics learning. Žakelj et al (2024), through an experimental study of 231 elementary school students, found that the group that obtained active learning and experiential learning showed better improvements than the control group at various levels of mathematics knowledge. These results show that active learning experiences can help students build deeper mathematical understanding and develop problem-solving skills. Research by Edo et al (2023) also found that experiential learning has an influence on students' performance in mathematics learning, while Aulia et al (2023) report that experiential learning can be used to develop mathematical creative thinking skills.

The difference in results between the experimental group and the control group can also be understood from the difference in the characteristics of the learning process. Discovery learning basically provides an opportunity for students to discover concepts through a process of exploration and investigation. However, if it is not systematically accompanied by contextual experience, reflection, meaning, and reapplication of concepts, the discovery process can end in mastery of concepts that are still procedural. On the other hand, deep learning-based experiential learning provides a learning cycle that allows students to experience problems, reflect on experiences, construct concepts, and retest the concept through new situations. The cycle has a strong compatibility with the characteristics of mathematical literacy because students are required to move from a real context to a mathematical representation, carry out a

mathematically process, obtain a solution, and then reinterpret the solution in the initial context.

The results of the N-gain analysis further strengthened the findings. The experimental group obtained an average N-gain of 0.6533 with a minimum value of 0.56 and a maximum of 0.78. Based on the classification of N-gain, the average was in the medium category. Meanwhile, the control group obtained an average N-gain of 0.1164 with a minimum value of -0.28 and a maximum of 0.35 which was included in the low category. This difference shows that the effectiveness of deep learning-based experiential learning is not only seen in the final score, but also in the magnitude of the improvement in ability that occurs during the learning process.

An N-gain value of 0.6533 indicates that the experimental group was able to achieve a fairly substantial improvement from the initial condition to the final condition. On the other hand, the N-gain value of 0.1164 in the control group indicates that the improvement in mathematical literacy ability is relatively small. In fact, the minimum N-gain value of -0.28 indicates that in some students in the control group there was a decrease in scores from pretest to posttest. This condition indicates that the discovery learning that was applied has not provided a consistent improvement in all students. On the other hand, the N-gain range of the experimental group which was between 0.56 and 0.78 showed a more consistent pattern of improvement.

These findings are relevant to the research of Sun and Xiao (2023) who developed a structural model of learning engagement and basic mathematics competencies based on experiential learning. The results of the study show that there is a relationship between student involvement in the learning process and the development of mathematical competence. Thus, experiential learning is not only oriented to experiential activities, but can also increase student involvement which ultimately supports the development of mathematical competence.

The improvement of mathematical literacy in the experimental group can also be explained through the process of knowledge transfer. When students gain concrete experiences and are then asked to reflect on the experience, they not only remember the completion procedure, but also build an understanding of when, why, and how a mathematical concept is used. This kind of understanding is very important for mathematical literacy because literacy problems are generally presented in a different context than the examples given during learning. Students must be able to recognize the mathematical structure of a new situation and choose appropriate strategies. Therefore, learning that emphasizes understanding and transfer is more relevant to developing mathematical literacy than learning that emphasizes only procedural exercises.

The findings of this study also have implications for mathematics learning that is oriented towards higher-level thinking skills. Higher results in the experimental group show that the integration of experiential learning with deep learning can be an alternative to shift mathematics learning from the orientation of mastering procedures to learning that emphasizes understanding, reflection, problem-solving, and application of concepts. This is in line with the results of research by Salma & Wijayanti (2025) who through a literature review found that the deep learning approach in mathematics learning can support deeper conceptual understanding and increase students' active involvement in the learning process.

Overall, the results of the study show that deep learning-based experiential learning is more effective than discovery learning in improving mathematical literacy skills. These advantages are shown by three main findings, namely a higher average increase in scores in the experimental group, a statistically significant difference in the average posttest, and a higher N-gain value. The average N-gain of 0.6533 in the experimental group compared to 0.1164 in the control group shows that deep learning-based experiential learning is able to provide a much greater improvement in ability. These findings show that the integration of concrete experiences, reflection, concept meaning, and application in a mindful, meaningful, and joyful learning environment is a potential combination to develop students' mathematical literacy.

When compared to previous research, the novelty of this research lies in the integration of experiential learning with deep learning principles in a learning design that is specifically directed to improve students' mathematical literacy. Previous research tends to place

experiential learning as an approach to strengthen learning experiences and mathematical performance, while deep learning studies emphasize more on the quality of the learning process through the principles of mindful, meaningful, and joyful. This research brings together the two perspectives so that concrete experiences, reflective observation, conceptualization, and active experimentation are not only a series of learning activities, but are also directed to build learning awareness, concept meaning, and positive student engagement. Thus, the novelty of the research is not just the use of two approaches simultaneously, but lies in the integration of the functions of the two to build a learning process that is relevant to the characteristics of mathematical literacy.

The main findings of the study showed that the group that obtained deep learning-based experiential learning experienced a higher increase in mathematical literacy than the discovery learning group. The average score of the experimental group increased from 43.87 to 80.16, while the control group increased from 43.96 to 61.48. The difference between the average posttest score of 18.68 points and the result of the independent sample t-test of $t = 12.004$ with $p < 0.001$ showed a very significant difference. The findings were strengthened by an N-gain value of 0.6533 in the experimental group in the medium category, while the control group only reached 0.1164 in the low category. This result is important because it shows that the advantage of the treatment is not only reflected in the final score, but also in the magnitude of the change in mathematical literacy ability from the initial condition to the final condition.

The findings of this study are in line with Žakelj et al. (2024) who show that active learning and experiential learning provide better results in various aspects of mathematics learning outcomes than control learning. This consistency can be explained because both studies provide space for students to be actively involved in the learning process, rather than just accepting ready-made procedures. The results of Edo et al.'s (2023) research also support these findings by showing the influence of experiential learning on the performance of junior high school students in mathematics learning. Similarly, Aulia et al. (2023) show that experiential learning can support mathematical creative thinking skills. The similarity of these results indicates that concrete experiences, exploratory activities, and student involvement are mechanisms that have the potential to strengthen cognitive processes in mathematics learning.

This research is also in line with the findings of Yılmaz and Kesebir (2023) who show the relevance of experiential learning in mathematical modeling activities. Modeling and mathematical literacy both require students to relate real situations to mathematical representations, choose relevant concepts, perform the mathematization process, and reinterpret the results in context. In this study, these relationships are strengthened through cycles of experience, reflection, conceptualization, and active experimentation. Therefore, the increase in mathematical literacy can be understood as a consequence of the availability of more systematic opportunities for students to move from experience to understanding and then use that understanding in new situations.

From the perspective of deep learning, the findings of this study are in line with Hardianti et al. (2025) who report that the synergy of Problem-Based Learning and deep learning pedagogy can improve mathematical literacy, as well as with Siregar et al. (2025a) who emphasize the importance of meaningful, mindful, and joyful learning in the design of mathematics learning. Kurnianingsih et al. (2026) also emphasized that the integration of these three principles can strengthen reflection and the development of metacognitive abilities. The similarity of these findings can be explained by the existence of a learning mechanism that encourages students not to stop at problem-solving activities, but to be aware of their thinking processes, connect new knowledge with previous experiences, and actively engage in learning. Thus, the principle of deep learning functions as a reinforcement of the quality of the experiential learning process, not as a stand-alone learning stage.

The difference between the results of this study and some previous studies mainly lies in the focus of learning outcomes, subject characteristics, and comparison groups. Žakelj et al. (2024) focused on the mathematics learning outcomes of elementary school students, while this study involved 120 students in grade VIII of junior high school and specifically measured mathematics literacy. The research of Hardianti et al. (2025) used Problem-Based Learning as

the main model, while this study used experiential learning enriched by deep learning principles and compared it with discovery learning. These differences allow this study to provide more specific empirical evidence on the effectiveness of integrating learning experiences and deep learning on mathematics literacy at the junior high school level. The differences in context, learning design, task characteristics, and learning outcome variables can also explain why the magnitude of the increase in this study is not entirely the same as the previous research.

The academic contribution of this research is to expand the understanding that experiential learning can be positioned not only as an experiential approach, but as a learning framework that can be designed to produce deeper learning. The integration provides a perspective that concrete experiences need to be followed by directed reflection, concept formation, and reapplication of concepts in new situations so that experience truly contributes to mathematical literacy. This finding complements the research of Salma and Wijayanti (2025) which shows the potential of deep learning approaches in mathematics learning and strengthens the research direction of Wardono et al. (2025) on the importance of contextual and literacy-oriented learning. Thus, this study fills the gap between experiential learning studies and deep learning studies which were previously discussed more often separately.

Practically, the results of the study imply that mathematics teachers can design literacy learning through experiences that are close to students' lives, followed by reflection activities to examine strategies and mistakes, strengthen mathematical concepts, and apply concepts to different problems or contexts. Teachers also need to keep the learning experience aware, meaningful, and encouraging so that students have the opportunity to try strategies, discuss, give reasons, and evaluate results. However, the application of this model requires teachers' readiness to choose the context of the problem, develop reflective questions, manage time, and prepare assessments that are able to capture the mathematics literacy process. This is in line with Andayanie et al. (2025) who emphasize that the implementation of mindful, meaningful, and joyful learning requires teacher readiness and adjustment of the learning system.

Academic implications and follow-up research also need to be considered. Future research can test this model on different math materials, different levels of education, longer duration of interventions, and more diverse sample sizes to see the consistency of its effectiveness. Advanced research can also use mixed methods design to uncover the process by which experience and reflection produce changes in each indicator of mathematical literacy, not just changes in total scores. In addition, variables such as habits of mind, motivation, learning engagement, problem-solving ability, and metacognitive abilities can be studied as mediators or moderators. In this direction, the development of deep learning-based experiential learning can move from evidence of effectiveness to an understanding of learning mechanisms and the development of stronger theories.

Thus, the overall empirical evidence and comparison with previous research show that deep learning-based experiential learning has added value in the aspects of experience integration, reflection, concept construction, application, and the quality of mindful, meaningful, and joyful learning. These advantages make the model studied relevant as an alternative to mathematics learning that not only pursues the accuracy of answers, but also the ability of students to use mathematics to understand, formulate, solve, and interpret problems in a meaningful context.

Overall, this study fills the gap between the two research clusters that developed in parallel. The first cluster shows that experiential learning can improve outcomes and engagement in mathematics learning, while the second cluster shows that deep learning can create more meaningful, mindful, and joyful learning. This study connects the two clusters and tests their impact directly on the mathematical literacy of junior high school students. The results show that the integration of experience, reflection, conceptualization, experimentation, and mindful–meaningful–joyful principles is not only consistent with learning theory, but also results in strong empirical differences. Thus, this study offers the perspective that improving mathematical literacy requires experiential design that makes students experience, realize,

interpret, construct, and transfer mathematical knowledge (Hidayatulloh et al., 2025; Sumliyah et al., 2025; Amelia & Khotimah, 2025).

In terms of research development, future studies need to test the effectiveness of models at different levels and mathematical materials, including change and relationship materials, which are one of the important domains of mathematical literacy. Research can also use mixed methods design to explain the processes that produce quantitative improvement, for example through student answer analysis, reflection observations, interviews, and recordings of the discussion process. Follow-up studies can test whether the influence of the model is mediated by engagement, self-regulated learning, metacognition, self-efficacy, or habits of mind. This direction is relevant because mathematics literacy studies show a relationship between cognitive-affective characteristics and problem-solving performance (Aisyah & Juandi, 2022; Pertiwi et al., 2022; Sun & Xiao, 2023), while deep learning studies show the need to strengthen reflective practices and teacher readiness (Kurnianingsih et al., 2026; Gusti & Amastini, 2025).

The practical implications of the research are the need for teachers to design mathematics literacy learning in a consistent cycle. At the concrete experience stage, teachers can present real-life problems; at the reflection stage, students analyze information, strategies, and errors; at the conceptualization stage, students build relationships between experiences and mathematical concepts; and at the active experimentation stage, students test concepts in new contexts. This pattern is in line with deep learning principles that place meaningful experiences, awareness of the learning process, and positive atmosphere as mutually reinforcing parts (Andayanie et al., 2025; Siregar et al., 2025; Widyastuti et al., 2025; Ricita et al., 2025; Prasetiya et al., 2025). Teachers also need to anticipate obstacles in the form of time constraints, pedagogical readiness, facilities, and student heterogeneity (Pujawati et al., 2025; Nafi'ah & Faruq, 2025).

The academic contribution of this research is on three levels. First, at the conceptual level, this study shows that experiential learning can function as a learning cycle structure, while deep learning can function as an orientation for the quality of learning experiences. Second, at the empirical level, this study provides quasi-experimental evidence that the integration of the two provides a higher increase in mathematical literacy than discovery learning. Third, at the pedagogical level, this research offers a basis for teachers to design learning experiences that do not stop at concrete activities, but continue with reflection, conceptualization, and application. This contribution enriches the still developing deep learning research and at the same time expands the study of experiential learning in mathematics education (Nafi'ah & Faruq, 2025; Pujawati et al., 2025; Slamet et al., 2025; Nurjannah & Ramlah, 2025).

There are also differences that need to be considered with previous research. Some studies use mathematical literacy as a ability that is analyzed descriptively or associated with individual characteristics, such as self-efficacy, self-concept, independence, and cognitive style (Pertiwi et al., 2022; Ismail et al., 2024; Pertiwi & Setyaningsih, 2024; Utama et al., 2024). Other studies use PBL, PMRI, ethnomathematics, or ELPSA as interventions (Purnaningtyas & Safa'atullah, 2023; Faradilla et al., 2024; Pratiwi & Rosita, 2024; Firmansyah et al., 2025). Meanwhile, this study tested a model that explicitly combines experiential learning and deep learning and compared it with discovery learning. These methodological differences may explain why the magnitude of the increase cannot be directly equated with previous studies.

Comparison with research oriented to mathematical literacy shows that contextual approaches and real-life experiences are important components. Research by Ristanti and Murdiyani (2021) shows that ethnomathematics-based learning tools can be directed to achieve mathematical literacy, while Tusadiyah et al. (2024) found that puzzle-assisted REACT strategies can support mathematical literacy and adaptive reasoning. Maulina et al.'s (2024) research also shows the benefits of ethnomathematics-based learning on mathematical literacy. Firmansyah et al.'s (2025) research on ELPSA shows that frameworks that connect experiences, language, symbols, and applications can be used to improve mathematical literacy. These findings reinforce the argument that mathematical literacy develops better when students relate experiences and context to mathematical representations and structures.

In terms of deep learning, the results support the view that deep learning is not enough to be understood as more or more difficult activities, but as a process that produces

understanding, meaning, awareness, and engagement. Siregar et al. (2025) explain that meaningful learning is built through real context and open problems, mindful learning through awareness of the thought process and reflection, while joyful learning is through active participation and a positive learning atmosphere. Kurnianingsih et al. (2026) emphasized that the balance of these three dimensions is important because the implementation of deep learning is often more dominant in meaningful and joyful learning while the mindful dimension requires systematic reflective practice. The findings of this study show that these dimensions can be integrated into the experiential learning cycle. These results are also in line with Salma and Wijayanti (2025), Rahayu et al. (2025), and Gusti and Amastini (2025).

The research findings are also in line with studies that link learning experiences with problem-solving and reasoning skills. The development of experiential learning-based e-modules has been reported to support students' mathematical reasoning (Suanto et al., 2022), while augmented reality-assisted experiential learning is reported to be related to self-regulated learning and mathematical reasoning (Maulida et al., 2024). Recent meta-analyses also show the positive effects of experiential learning on mathematics achievement and engagement (Caritan, 2025). These similarities may be due to hands-on activities, collaboration, authentic problem-solving, and opportunities for reflection. However, this study has a more specific focus because it tests mathematical literacy as the main outcome and uses discovery learning as a comparison group.

Consistency with experiential learning research can be explained through the characteristics of concrete experiences and reflective activities. When students encounter problems close to life, they gain opportunities to identify information, try strategies, compare results, and improve ways of thinking. These mechanisms help transform mathematical knowledge from procedural knowledge to knowledge that can be used flexibly. Uyen et al. (2022) show that experiential learning in arithmetic and geometry can improve achievement and attitudes towards mathematics, while Sun and Xiao (2023) found a link between learning engagement and mathematical competence in experiential learning. Similar findings are also seen in research on understanding mathematical concepts through experiential learning (Rohani et al., 2024) and the use of experiential learning in trigonometry learning (Mahdiyyah, 2024).

The main findings of the study showed that the average math literacy of the experimental group increased from 43.87 to 80.16, while the control group increased from 43.96 to 61.48. The difference between the posttest was 18.68 points and the results of the independent sample t-test were 12.004 with a $p < 0.001$ showed a very significant difference. The experimental group's n-gain of 0.6533 was in the medium category and much higher than the control group's 0.1164 in the low category. These findings provide empirical evidence that the integration of experiential learning and deep learning has added value compared to discovery learning in the context of mathematical literacy. These results are consistent with experimental research that shows that experiential learning can improve math achievement compared to comparative learning (Uyen et al., 2022; Edo et al., 2023; Žakelj et al., 2024; Bajpai & Pandey, 2024), as well as studies that show that deep learning has the potential to strengthen conceptual understanding and student engagement (Salma & Wijayanti, 2025; Wahyuningsih et al., 2026).

This novelty is even more important because the variables tied to this study are not just learning outcomes or concept understanding, but mathematical literacy that requires students to understand the context, formulate situations mathematically, use concepts and procedures, and interpret results. Studies on mathematical literacy show that this ability still faces problems in the process of understanding information, doing math, choosing strategies, and providing appropriate interpretations (Aisyah & Juandi, 2022; Pertiwi et al., 2022; Rusmining & Sawitri, 2022; Harisman et al., 2023). Other research also shows that mathematical literacy is influenced by students' cognitive and affective characteristics, including cognitive style, learning independence, self-efficacy, and reasoning ability (Astuti & Wardono, 2022; Ismail et al., 2024; Purnomo & Utami, 2023; Utama et al., 2024).

The novelty of this research lies in the integration of two pedagogical perspectives that have been more often studied separately, namely experiential learning and deep learning.

Experiential learning provides the structure of the learning process through concrete experiences, reflection, conceptualization, and active experimentation, while deep learning provides quality orientation through the principles of mindful, meaningful, and joyful learning. This combination makes experience not just an activity, but a source of knowledge construction directed at conceptual understanding, reflection, transfer, and student engagement. This position is different from research that only tests experiential learning on mathematics learning outcomes or examines deep learning as a conceptual pedagogical approach. Previous empirical evidence shows the benefits of experiential learning on mathematics achievement (Uyen et al., 2022; Edo et al., 2023; Žakelj et al., 2024), while deep learning studies emphasize the importance of integrating mindful, meaningful, and joyful learning (Andayanie et al., 2025; Siregar et al., 2025; Kurnianingsih et al., 2026).

CONCLUSION

Based on the results of the study, it can be concluded that the deep learning-based experiential learning model is effective in improving students' mathematical literacy skills. The average score of the experimental group increased from 43.87 in the pretest to 80.16 in the posttest, while the control group increased from 43.96 to 61.48. The results of the prerequisite test showed that the data was distributed normally and homogeneously with a significance value of > 0.05. Furthermore, the independent sample t-test showed a significant difference between the experimental and control groups with a value of $t = 12.004$ and $p < 0.001$. The results of the N-gain test also showed an increase in the experimental group of 0.6533 in the medium category, higher than the control group of 0.1164 in the low category. Thus, deep learning-based experiential learning has been proven to be more effective than discovery learning in improving students' mathematical literacy skills. This effectiveness is supported by learning that integrates experience, reflection, conceptual understanding, application, and the principles of mindful, meaningful, and joyful learning.

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