Journal of Advanced Sciences and Mathematics Education
Volume 6, Issue 2, 762-778.
e_ISSN: 2798-1606
DOI: 10.58524/jasme.v6i2.1371

Lesson study-based mathematics instruction with a deep learning approach for enhancing elementary students' mathematical literacy

Ahmad Yani T*
Universitas Tanjungpura, INDONESIA

Akbar Ramadhan
Universitas Tanjungpura, INDONESIA

Heri Sutrisno
Universitas Tanjungpura, INDONESIA

Dyan Hayuningtrisna Hadiwangsa
Universitas Tanjungpura, INDONESIA

Dona Fitriawan
Universitas Tanjungpura, INDONESIA

Article Info

Article history:

Received: April 10, 2026
Revised: May 17, 2026
Accepted: June 26, 2026

Keywords:

Deep Learning Approach; Lesson Study; Mathematical Literacy Skills; Public Elementary Schools; Two-Dimensional Shapes.

Abstract

Background: Mathematical literacy is a fundamental competency that enables students to apply mathematical knowledge in real-life situations. However, Indonesian students continue to demonstrate relatively low mathematical literacy performance, as indicated by the 2022 PISA results. Similar challenges are evident among elementary school students in Pontianak, who often experience difficulties in solving contextual mathematical problems.
Aim: This study aimed to examine differences in mathematical literacy skills, determine the magnitude of the instructional effect, analyze the implementation process, and describe students' mathematical literacy performance following lesson study-based mathematics instruction with a deep learning approach.
Method: A mixed-methods approach with an embedded experimental design was employed. Quantitative data were collected through a quasi-experimental design involving 55 fourth-grade students in the experimental group and 65 students in the control group. Qualitative data were obtained through classroom observations and lesson study reflections. Data were analyzed using the Mann–Whitney U test and Cohen's d effect size.
Results: The findings revealed a significant difference in mathematical literacy skills between the experimental and control groups ($p < .001$). The intervention produced a Cohen's d value of 0.3189, indicating a small-to-moderate practical effect. Qualitative findings showed that the lesson study cycle fostered a structured, collaborative, and reflective learning environment that enhanced students' engagement and conceptual understanding.
Conclusion: Lesson study-based mathematics instruction with a deep learning approach effectively enhances elementary students' mathematical literacy by promoting contextual understanding, reflective learning, and meaningful application of mathematical concepts.

To cite this article: T. Yani., A., Ramadhan, A., Sutrisno, H., Hadiwangsa, D. H. & Fitriawan, D. (2026). Lesson study-based mathematics instruction with a deep learning approach for enhancing elementary students' mathematical literacy. *Journal of Advanced Sciences and Mathematics Education, 6*(2), 762-778.

INTRODUCTION

Education plays a fundamental role in developing high-quality human resources capable of responding to the demands of an increasingly complex global society. Through education, individuals are expected to develop cognitive abilities, practical skills, and positive character traits that enable them to adapt and contribute effectively to social and economic development (Akın, 2022; Cao et al., 2021; Ye et al., 2023). Consequently, the quality of teaching and learning processes at all levels of education has become a major concern for policymakers and educators worldwide. Effective learning should not only facilitate the acquisition of knowledge but also encourage students to apply their

***Corresponding author:**
Ahmad Yani T, Universitas Tanjungpura, Indonesia
ahmad.yani.t@fkip.untan.ac.id

understanding meaningfully in real-life situations. Within this context, mathematics occupies a strategic position because it contributes significantly to the development of logical, analytical, and critical thinking skills. Mathematics learning is expected to help students understand relationships, solve problems, and make reasoned decisions based on quantitative information. However, many students continue to perceive mathematics as a difficult and abstract subject that is disconnected from their everyday experiences. Such perceptions often reduce students' interest in learning mathematics and limit their engagement with mathematical ideas. As a consequence, students frequently experience difficulties when required to apply mathematical concepts to solve contextual problems. This condition ultimately contributes to the relatively low level of mathematical literacy demonstrated by many students (Sumliyah et al., 2025).

Mathematical literacy has become one of the most important educational outcomes in contemporary mathematics education because it reflects students' ability to use mathematics in meaningful and practical ways. According to the OECD, mathematical literacy refers to an individual's capacity to formulate, employ, and interpret mathematics in a variety of real-world contexts (Almarashdi & Jarrah, 2023; Bolstad, 2023; Çakıroğlu et al., 2024). This competency involves mathematical reasoning as well as the use of concepts, procedures, facts, and tools to explain phenomena and make informed decisions. Students who possess strong mathematical literacy are able to connect mathematical ideas with situations encountered in daily life. They are also capable of interpreting quantitative information, evaluating solutions, and communicating mathematical reasoning effectively. Despite the importance of these competencies, the mathematical literacy performance of Indonesian students remains relatively low compared with that of students from many other countries. Based on the results of the Programme for International Student Assessment (PISA) conducted in 2022, Indonesia ranked 71st among 81 participating countries with a score of 366, representing a decline of 13 points from the previous assessment cycle. This score was substantially below the international average of 472, indicating persistent challenges in mathematics education. These findings suggest that many students still rely heavily on memorization and procedural knowledge rather than conceptual understanding and contextual application of mathematics. Therefore, improving mathematical literacy has become an urgent priority for educational stakeholders in Indonesia.

The issue of mathematical literacy is also evident at the local level, particularly in Pontianak City and the broader West Kalimantan region. Research on literacy- and numeracy-based learning in accredited elementary schools in Pontianak revealed that many students still encounter difficulties when applying mathematical concepts to contextual situations. These findings indicate that students often struggle to transfer classroom knowledge to authentic problems encountered in everyday life. Similar concerns have been reported regarding the numeracy performance of elementary school students in West Kalimantan. According to students' numeracy competencies remain relatively low, highlighting the need for instructional innovations that support deeper understanding and practical application of mathematical concepts (Sakurai & Goos, 2023; Torres-Peña et al., 2025). The persistence of these challenges suggests that conventional approaches to mathematics teaching may not adequately address students' learning needs. In many classrooms, learning activities continue to focus primarily on procedural exercises and routine problem-solving tasks (Ezeamuzie et al., 2022; Glazewski & Ertmer, 2020; Olivares et al., 2021). Consequently, students have limited opportunities to develop reasoning skills, explore mathematical relationships, and engage in meaningful reflection (Dolapcioglu & Doğanay, 2022; Ingram et al., 2020; Nilimaa, 2023; Öz & Işık, 2024). The evidence from both national and local contexts indicates that mathematical literacy remains a significant educational challenge requiring immediate attention. Therefore, more effective and innovative instructional strategies are needed to help students develop stronger mathematical literacy competencies.

Although mathematical literacy has become a major focus in mathematics education research, existing studies have primarily examined its conceptual foundations, students' experiences with literacy-oriented tasks, and the implementation of instructional approaches such as inquiry-based learning, STEM education, and realistic mathematics education (Bolstad, 2023; Fauzan et al., 2024; Manfreda Kolar & Hodnik, 2021). At the same time, lesson study research has largely concentrated on teacher professional development, collaborative lesson design, and instructional improvement, with limited attention given to mathematical literacy as a primary learning outcome (Jansen et al., 2021). Furthermore, studies in elementary mathematics education have predominantly focused on student achievement, motivation, and general learning effectiveness rather than on the development of mathematical literacy through integrated pedagogical innovations (Lazi et al., 2021; Pellegrini et al., 2021). Although recent educational reforms have increasingly emphasized meaningful and student-centered learning, empirical studies investigating the application of deep learning as a pedagogical approach in elementary mathematics classrooms remain scarce, while the term "deep learning" is still more commonly associated with artificial intelligence and computational sciences than with mathematics pedagogy (Tian et al., 2022; Zhang et al., 2020). More importantly, little empirical evidence exists regarding the integration of lesson study and a deep learning approach within mathematics instruction to enhance elementary students' mathematical literacy, particularly in developing countries and within the Indonesian educational context. Moreover, previous studies have generally examined instructional effectiveness through quantitative learning outcomes alone, providing limited insight into how collaborative lesson planning, implementation, observation, and reflection contribute to students' literacy development. Therefore, a significant research gap remains concerning the effectiveness and implementation process of lesson study-based mathematics instruction with a deep learning approach for enhancing elementary students' mathematical literacy, highlighting the need for further investigation through a mixed-methods perspective.

This study aims to investigate the effectiveness of lesson study-based mathematics instruction with a deep learning approach in enhancing elementary students' mathematical literacy on the topic of two-dimensional shapes. Specifically, the study seeks to determine whether significant differences exist in mathematical literacy skills between students who participate in lesson study-based deep learning instruction and those who receive conventional mathematics instruction. The study also aims to measure the magnitude of the instructional effect on students' mathematical literacy performance. In addition, it seeks to analyze the implementation process of lesson study-based mathematics instruction through collaborative planning, classroom observation, and reflective evaluation activities. Particular attention is given to how the integration of lesson study and deep learning influences students' engagement with mathematical concepts. The study further aims to describe students' mathematical literacy abilities following their participation in the instructional intervention. These abilities include students' capacity to formulate, apply, and interpret mathematical concepts within contextual situations related to two-dimensional shapes. By combining quantitative and qualitative data, the study seeks to provide a comprehensive understanding of both instructional effectiveness and learning processes. The findings are expected to contribute to the growing body of literature on mathematical literacy and instructional innovation in elementary mathematics education. Ultimately, this research aims to provide empirical evidence supporting the integration of lesson study and deep learning as an effective approach for fostering mathematical literacy among elementary school students.

LITERATURE REVIEW

Mathematical literacy has become a central construct in contemporary mathematics education because it emphasizes the application of mathematical knowledge in meaningful contexts rather than the mere mastery of computational procedures. The Organisation for Economic Co-operation and Development (OECD) defines mathematical literacy as an individual's ability to formulate, employ, and interpret mathematics in various real-world situations. This competency requires students to identify mathematical relationships, select appropriate strategies, and communicate solutions effectively. Mathematical literacy also involves reasoning, critical thinking, and decision-making processes that enable individuals to solve authentic problems encountered in everyday life (Szabo et al., 2020). Unlike traditional mathematics achievement, mathematical literacy focuses on how mathematical knowledge can be used beyond classroom settings. Students with strong mathematical literacy are able to connect mathematical concepts with social, economic, scientific, and technological issues (Bolstad, 2023; Zeng, 2025). Consequently, mathematical literacy has become an important indicator of educational quality in many countries. International assessments such as PISA place considerable emphasis on mathematical literacy because it reflects students' preparedness for future challenges. Educational researchers increasingly recognize mathematical literacy as a fundamental competency for lifelong learning and active citizenship. Therefore, the development of mathematical literacy has become one of the primary objectives of mathematics education in the twenty-first century.

The development of mathematical literacy should begin at the elementary school level because early mathematical experiences significantly influence students' future learning trajectories. Elementary education provides the foundation upon which students construct mathematical understanding and reasoning skills. At this stage, students begin to develop the ability to recognize patterns, interpret information, and solve simple contextual problems. However, many elementary students continue to experience difficulties when asked to apply mathematical concepts outside routine classroom exercises (Kundu et al., 2021; Suh et al., 2021; Vale & Barbosa, 2023). These difficulties often arise because learning activities focus primarily on procedural fluency rather than conceptual understanding. As a result, students may successfully perform calculations while struggling to explain the meaning of their solutions. Research has shown that meaningful mathematical experiences during elementary education contribute significantly to later academic achievement and problem-solving competence (W. Chen, 2025; Lai et al., 2020; Lazi et al., 2021; Spencer et al., 2022; Torres-Peña et al., 2025). Furthermore, students who are exposed to contextual learning opportunities tend to demonstrate stronger reasoning and mathematical communication skills. The elementary years therefore represent a critical period for fostering mathematical literacy through effective instructional practices. Consequently, instructional approaches that encourage active engagement, contextual understanding, and reflective thinking are particularly important in elementary mathematics education.

One instructional approach that has gained increasing attention in recent years is the deep learning approach. In educational contexts, deep learning refers to a learning process in which students actively construct knowledge, connect new information with prior understanding, and apply concepts in meaningful situations (Y.-C. Chen & Techawitthayachinda, 2021; Jiang, 2022; Kovač et al., 2025; Salinas-Navarro et al., 2024; Weng et al., 2023). This approach differs substantially from surface learning, which is primarily characterized by memorization and reproduction of information. Deep learning encourages students to explore ideas critically, reflect on their understanding, and engage in meaningful knowledge construction. The approach is often conceptualized through three interconnected dimensions, namely meaningful learning, mindful learning, and joyful learning. Meaningful learning emphasizes conceptual understanding and relevance to students' experiences.

Mindful learning encourages students to become aware of their thinking processes and learning strategies. Joyful learning creates positive emotional engagement that supports sustained participation and motivation. Through these dimensions, deep learning promotes higher-order thinking skills and conceptual understanding. Therefore, the deep learning approach has considerable potential to support the development of mathematical literacy by encouraging students to understand, interpret, and apply mathematical concepts in authentic contexts.

In addition to instructional approaches, teacher collaboration plays an important role in improving the quality of mathematics learning. Lesson study is widely recognized as a collaborative professional development model that supports continuous instructional improvement through systematic reflection. Originating in Japan, lesson study involves a cycle of planning, implementation, observation, and reflection commonly referred to as plan, do, and see (Hervas & Medina, 2020; Seleznyov, 2019). During the planning stage, teachers collaboratively design learning activities and anticipate students' responses. The implementation stage allows teachers to observe students' learning processes and collect evidence regarding instructional effectiveness. Reflection activities enable teachers to evaluate learning outcomes and identify opportunities for improvement. This collaborative process encourages teachers to develop a deeper understanding of students' learning needs and classroom interactions. Previous studies have demonstrated that lesson study contributes to improved instructional quality, teacher professionalism, and student engagement (Dibaba et al., 2025; Fox & Poultney, 2020; Ji, 2023; Kelly & Abruzzo, 2021). Moreover, lesson study promotes reflective teaching practices that support evidence-based decision-making in classroom instruction. Consequently, lesson study has become an effective framework for enhancing mathematics teaching and learning in various educational contexts.

The integration of lesson study and the deep learning approach offers a promising framework for enhancing mathematical literacy among elementary school students. Deep learning provides pedagogical principles that emphasize meaningful understanding, active engagement, and contextual application of knowledge (Darling-Hammond et al., 2020; Jiang, 2022; McPhail, 2021). At the same time, lesson study offers a collaborative mechanism through which teachers can design, implement, and refine deep learning practices systematically. Through collaborative lesson planning, teachers can develop learning activities that encourage students to formulate, apply, and interpret mathematical concepts in authentic situations (Dolapcioglu & Doğanay, 2022; Koskinen & Pitkäniemi, 2022; Nilimaa, 2023; Polman et al., 2021). Classroom observations conducted during lesson study cycles provide valuable insights into students' thinking processes and learning difficulties. Reflection activities further support continuous improvement by enabling teachers to adapt instructional strategies based on empirical classroom evidence. This combination creates a learning environment that is reflective, contextual, student-centered, and oriented toward conceptual understanding. Such conditions are highly relevant to the development of mathematical literacy because they encourage students to engage actively with mathematical ideas and real-world problems. Despite its theoretical potential, empirical evidence regarding the integration of lesson study and deep learning for mathematical literacy development remains limited. Therefore, further investigation is necessary to examine how lesson study-based mathematics instruction with a deep learning approach can effectively enhance elementary students' mathematical literacy.

METHOD

Research Design

This study employed a mixed-methods approach using an embedded experimental design, in which quantitative data served as the primary source of evidence and qualitative data were used to support, explain, and enrich the interpretation of the quantitative findings. The selection of this

design was based on the need to examine not only the effectiveness of lesson study-based mathematics instruction with a deep learning approach in improving students' mathematical literacy but also the instructional processes that occurred during the implementation. The quantitative component utilized a quasi-experimental design with a nonequivalent posttest-only control group design. In this design, the experimental group received mathematics instruction based on lesson study integrated with a deep learning approach, whereas the control group received conventional mathematics instruction. The absence of random assignment was due to practical and administrative considerations within the school setting. The posttest-only design was considered appropriate because the study focused on comparing students' mathematical literacy performance after the instructional intervention. Meanwhile, the qualitative component was conducted concurrently throughout the research process. Qualitative data were collected through classroom observations, field notes, and lesson study reflections to provide a detailed description of the implementation process and students' learning experiences. The integration of quantitative and qualitative evidence enabled a more comprehensive understanding of the effectiveness and implementation of the instructional intervention. Therefore, the mixed-methods embedded design was considered suitable for addressing the objectives of the present study.

Participants

The population of this study consisted of fourth-grade students enrolled in public elementary schools in Pontianak City, West Kalimantan Province, Indonesia. The study focused on elementary school students because mathematical literacy development should be established at an early stage of formal education. Participants were selected using purposive sampling, a non-probability sampling technique that involves selecting participants based on predetermined criteria relevant to the research objectives. The criteria included school accessibility, administrative approval, and the suitability of implementing lesson study activities within the school environment. Based on these considerations, two public elementary schools were selected as research sites. SD Negeri 09 Pontianak Barat was assigned as the experimental group and consisted of 55 fourth-grade students. SD Negeri 17 Pontianak Kota served as the control group and consisted of 65 fourth-grade students. Therefore, the total number of participants involved in the study was 120 students. Both groups studied the same mathematics topic, namely two-dimensional shapes, during the intervention period. This arrangement ensured that differences in learning outcomes could be attributed primarily to differences in instructional approaches rather than differences in learning content.

Instruments and Data Collection

Data were collected using both quantitative and qualitative instruments to capture students' mathematical literacy performance and the instructional processes that occurred during the intervention. The primary quantitative instrument was a mathematical literacy test consisting of 20 multiple-choice items. The test was designed to assess students' ability to formulate, apply, and interpret mathematical concepts in everyday situations related to two-dimensional shapes. The test items emphasized contextual problem-solving, mathematical reasoning, and the application of mathematical concepts in authentic situations. Following the completion of the instructional intervention, the test was administered to both the experimental and control groups. In addition to the mathematical literacy test, several qualitative instruments were utilized. Observation sheets were used to monitor students' participation, engagement, and learning behaviors during classroom activities. Field notes were employed to document significant classroom events, instructional interactions, and phenomena observed throughout the intervention. Reflection sheets were completed collaboratively by the model teacher, observers, and researchers during the lesson study process to evaluate instructional effectiveness and identify areas for improvement. Together, these

instruments provided comprehensive information regarding both learning outcomes and instructional implementation.

Data Analysis

Quantitative data were analyzed using descriptive and inferential statistical procedures with the assistance of IBM SPSS Statistics 25. Descriptive statistics were used to summarize students' mathematical literacy performance, including the mean, standard deviation, variance, maximum score, and minimum score. Before conducting hypothesis testing, a normality test was performed using the Kolmogorov–Smirnov test at a significance level of 0.05. The results indicated that the mathematical literacy data in both groups were not normally distributed. Consequently, a homogeneity test was not conducted, and nonparametric statistical procedures were employed. Differences in mathematical literacy performance between the experimental and control groups were analyzed using the Mann–Whitney U test. Statistical significance was determined at the 0.05 level. To evaluate the practical significance of the intervention, Cohen's d effect size was calculated using the difference between the mean scores of the two groups divided by the pooled standard deviation. The effect size values were interpreted according to Cohen's criteria, namely small effects ($d \leq 0.20$), moderate effects ($0.20 < d < 0.80$), and large effects ($d \geq 0.80$). Qualitative data were analyzed using the interactive model developed by Miles and Huberman (1994), which consists of data reduction, data display, and conclusion drawing. This analytical framework enabled the researchers to identify patterns, themes, and insights related to the implementation of lesson study-based mathematics instruction with a deep learning approach.

Research Procedure

The study was conducted from May 4 to May 15, 2026, at SD Negeri 09 Pontianak Barat and SD Negeri 17 Pontianak Kota. The research procedure consisted of three major stages: preparation, implementation, and reporting. During the preparation stage, preliminary interviews were conducted with classroom teachers to identify existing instructional practices and students' learning characteristics. Subsequently, the researchers collaborated with teachers to develop lesson plans, learning materials, observation instruments, and assessment tools based on the principles of lesson study and deep learning. The implementation stage consisted of three sessions for each group, including two instructional sessions and one posttest session. In the experimental group, mathematics instruction was implemented through the lesson study cycle comprising the plan, do, and see stages. During the plan stage, the research team and the model teacher collaboratively designed instructional activities and anticipated students' learning responses. During the do stage, instruction was carried out using deep learning syntax consisting of preparation, exploration, application, reflection, and evaluation activities. Observers documented classroom interactions and students' participation throughout the learning process. Finally, during the see stage, collaborative reflection sessions were conducted among the model teacher, observers, and researchers to evaluate instructional effectiveness and formulate improvements for subsequent lessons. The final stage involved data analysis, interpretation of findings, and preparation of the research report.

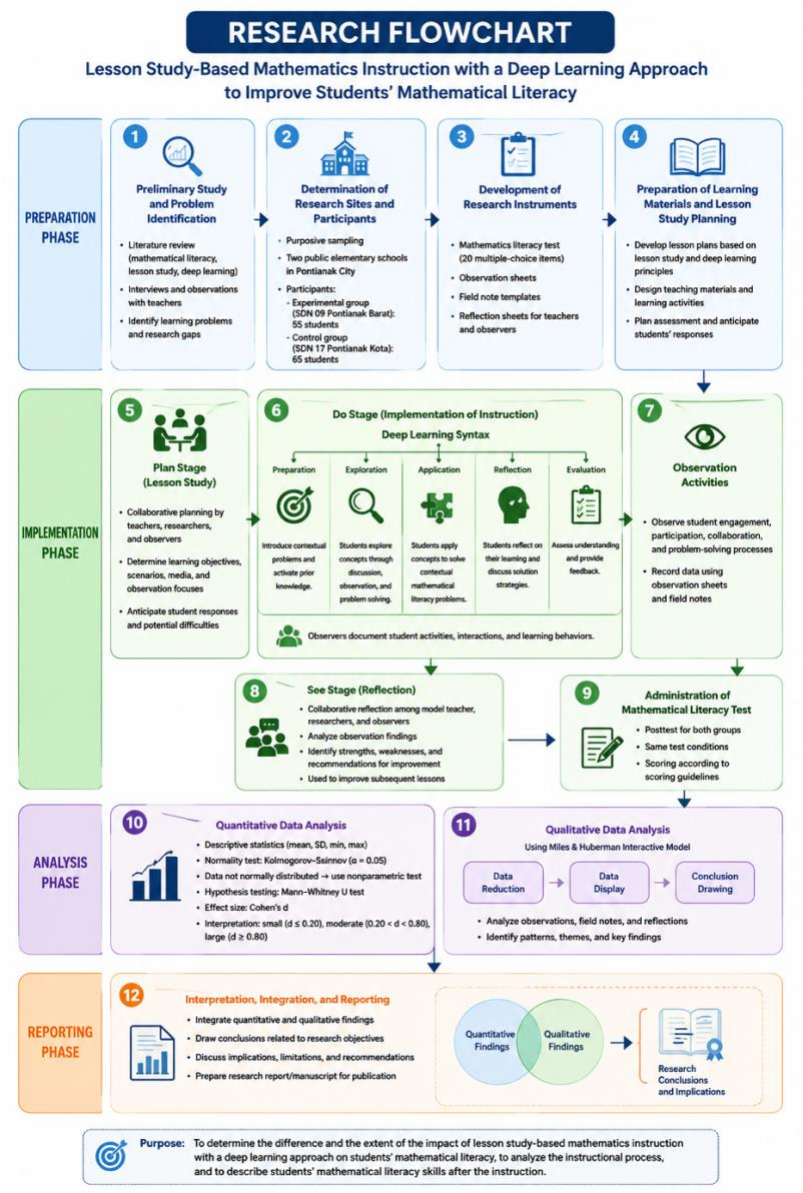

Figure 1. Research Procedure

RESULTS AND DISCUSSION

Results

Descriptive statistics

Test results from the experimental and control groups are needed to determine the students' mathematical literacy skills after they were given different treatments in the two classes. The following is a summary of the test results presented in the form of descriptive statistics.

Table 1. Descriptive Statistics for the Mathematical Literacy Test

Descriptive Statistics	Data Analysis	
	Experimental Group	Control Group
Number of Students	55	65
Highest Score	70	70
Lowest Score	5	0
Mean	29.09	20.15
Variance	199.158	199.976
Standard Deviation	14.112	14.141

Table 1 shows that the average mathematical literacy score for students in the experimental group was 29.09, while the average mathematical literacy score for students in the control group was 20.15. The difference between the two scores is 8.94, indicating that there is a difference in the average mathematical literacy scores between the two classes, with the experimental group having a higher average than the control group. However, specifically, to determine whether there is a difference in the average mathematical literacy ability between the two classes, a statistical test analysis must be conducted.

Normality tes

The normality of the mathematical literacy test data for the experimental and control groups was tested using the Kolmogorov-Smirnov test with the aid of IBM SPSS Statistics 25. The data were considered normally distributed if the significance level was > 0.05. The test results are shown in the following table.

Table 2. Results of the Normality Test

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Kelas Eksperimen	.165	55	.001	.911	55	.001
Kelas Kontrol	.167	55	.001	.923	55	.002

a. Lilliefors Significance Correction

Based on the test results, the significance values for both classes were 0.001 or less than $\alpha = 0.05$. Therefore, it can be concluded that the students' mathematical literacy test data are not normally distributed in either the experimental or control classes.

Hypothesis Test Results

Hypothesis testing in this study takes the form of a two-sample comparative hypothesis using interval or ratio scales. Based on the preliminary tests, it was found that the data from the two sample groups were not normally distributed; therefore, the nonparametric Mann-Whitney U test was used. The research hypotheses are as follows:

H_0 : $\mu_1 = \mu_2$, there was no difference in students' mathematical literacy skills regarding plane figures between students who received lesson study-based instruction using a deep learning approach and those who received conventional instruction.

H_a : $\mu_1 \neq \mu_2$, there is a difference in students' mathematical literacy skills regarding plane figures between students who received lesson study-based instruction using a deep learning approach and those who received conventional instruction.

In hypothesis testing, H_0 rejected if the value $t_{hitung} > t_{tabel}$ or significance level < 0.05. The test results are shown in the following table.

Table 1. Test Result Uji *Mann Whitney U*

Test Statistics[a]

	VAR00002
Mann-Whitney U	1097.000
Wilcoxon W	3242.000
Z	-3.663
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: VAR00001

Based on Table 3, it can be seen that the significance value is 0.000 or less than 0.05 which means H_0 rejected and H_a accepted. Thus, it can be concluded that there is a difference in students' mathematical literacy skills regarding plane figures between students who received lesson study-based instruction using a deep learning approach and those who received conventional instruction. The implementation of lesson study-based instruction using a deep learning approach has a greater impact on students' mathematical literacy skills compared to conventional instruction. The results of the effect size calculations for the mathematical literacy test data are as follows.

Table 4. Test Result *Effect size (Cohen's-d)*

d	**Interpretation**
0.3189	Medium

Based on the results in Table 4, it was found that the Cohen's d value is 0.3189. Referring to Table 3 regarding the interpretation of Cohen's d values, it was found that the results fall into the moderate category. This indicates that the implementation of lesson study-based learning with a deep learning approach has a significant impact on students' mathematical literacy skills in the area of plane figures compared to conventional learning.

Discussion

The results of the analysis show that the mathematical literacy skills of students in the experimental class at SD Negeri 09 Pontianak Barat were higher than those of students in the control class at SD Negeri 17 Pontianak Kota, as indicated by the mean scores of 29.09 and 20.15, respectively, with a difference of 8.94 points. These findings suggest that lesson study-based mathematics instruction with a deep learning approach was more effective in helping students understand, apply, and interpret concepts related to two-dimensional shapes. This advantage can be attributed to the collaborative, reflective, and student-centered learning process implemented through the plan, do, and see stages, which differs substantially from conventional instruction that tends to be teacher-centered and one-directional (Lewis & Perry, 2017). Furthermore, the deep learning approach emphasizes meaningful, mindful, and joyful learning experiences that encourage students to connect mathematical concepts with real-life contexts more actively (Feriyanto & Anjariyah, 2024). Consequently, students were provided with greater opportunities to construct knowledge, engage in reasoning processes, and develop contextual understanding. The statistical results further support this interpretation, as the Mann–Whitney U test revealed a significance value of 0.000, indicating that the observed difference between groups was statistically significant rather than occurring by chance.

In terms of practical significance, the calculated Cohen's d value of 0.3189 falls within the moderate effect category according to the criteria adopted in this study. Although the effect size was not large, it nevertheless indicates that the intervention produced a meaningful educational impact on students' mathematical literacy development. In elementary mathematics education, even moderate improvements should be considered important because literacy-related competencies generally require sustained instructional support and cannot be developed through short-term interventions alone. The observed improvement suggests that students benefited from learning experiences that emphasized conceptual understanding rather than procedural memorization. Moreover, students were actively involved in constructing mathematical meaning through exploration, discussion, and reflection activities, which are key characteristics of deep learning environments (Dahroni et al., 2025; Feriyanto & Anjariyah, 2024). These findings indicate that lesson study-based mathematics instruction with a deep learning approach represents a promising alternative for strengthening students' reasoning abilities, conceptual understanding, and contextual application of mathematical concepts.

The implementation of lesson study-based mathematics instruction with a deep learning approach at SD Negeri 09 Pontianak Barat proceeded systematically through the interconnected stages of plan, do, and see. During the planning stage, the model teacher and research team collaboratively designed instructional activities, anticipated students' difficulties, and prepared learning materials relevant to two-dimensional shapes. Such collaborative planning is considered essential for improving instructional quality and ensuring that learning activities are responsive to students' needs (Lewis & Perry, 2017). During the implementation stage, the application of deep learning principles encouraged students to participate actively in learning activities while connecting mathematical concepts to contextual situations. Although some students initially experienced difficulties when solving contextual mathematical literacy problems, their participation and engagement improved throughout the instructional process. During the reflection stage, lesson observations were analyzed collaboratively to identify strengths and weaknesses of the instructional implementation. The results of these reflections were subsequently used to refine instructional strategies and improve subsequent learning sessions. These findings support previous studies indicating that lesson study promotes reflective teaching practices and contributes positively to instructional effectiveness (Rahmawati, 2022; Sulaiman & Mansyur, 2024). Similar conclusions were also found that collaborative processes involving planning, implementation, observation, and reflection can improve teachers' instructional competencies and classroom management skills.

Students' mathematical literacy performance following the intervention also demonstrated notable differences between the experimental and control groups. The experimental group achieved a mean score of 29.09 with a standard deviation of 14.112, while the control group obtained a mean score of 20.15 with a standard deviation of 14.141. Although both groups achieved the same maximum score of 70, the minimum score in the experimental group was 5, whereas several students in the control group obtained a score of 0. The presence of zero scores in the control group suggests that some students were unable to respond adequately to mathematical literacy tasks. This condition is consistent with characteristics of conventional instruction that often provide limited opportunities for students to engage in contextual reasoning and meaningful problem-solving activities. In contrast, students who participated in lesson study-based mathematics instruction with a deep learning approach demonstrated greater competence in identifying relevant information, interpreting mathematical situations, and connecting geometric concepts to everyday experiences. They no longer relied solely on memorizing formulas and shape classifications but increasingly demonstrated an understanding of why particular mathematical procedures were used. Furthermore, students became more capable of explaining their reasoning and applying mathematical concepts systematically to solve contextual problems. These findings suggest that the intervention contributed to the development of deeper conceptual understanding and more sophisticated mathematical thinking processes.

The improvement observed in the experimental group can be explained by the characteristics of deep learning, which emphasize conceptual understanding, critical analysis, and contextual application of knowledge. According to deep learning provides students with opportunities to explore problems, collaborate with peers, and reflect on their learning experiences, thereby making abstract concepts more accessible and meaningful (Barokah & Mahmudah, 2025). These characteristics are particularly important in geometry learning because elementary school students tend to understand concepts more effectively when they are presented through concrete objects, visual representations, and hands-on activities. The results of the present study indicate that learning environments designed collaboratively and reflectively through lesson study can foster meaningful learning experiences that support mathematical literacy development. In such environments, teachers function not only as providers of information but also as facilitators who guide students in observing, reasoning, discussing, and interpreting mathematical situations. Consequently,

mathematical literacy extends beyond computational proficiency and becomes a broader competency involving the ability to formulate, use, and interpret mathematics in meaningful contexts (Surtika & U.s, 2024).

The present findings are also consistent with the work of argued that mathematical literacy is closely related to students' cognitive structures (Simin et al., 2022). Students with more developed cognitive structures tend to demonstrate higher levels of mathematical literacy, although continuous instructional support remains necessary. These findings reinforce the view that mathematics instruction should extend beyond formula memorization and repetitive practice. Instead, students should be provided with opportunities to identify problems, construct mathematical models, apply procedures, and evaluate solutions critically. That mathematical literacy is a crucial competency because it enables individuals to solve everyday problems and interpret quantitative information accurately. Therefore, efforts to strengthen mathematical literacy at the elementary level should focus on instructional approaches that engage students in meaningful thinking processes and contextual problem-solving activities. Such efforts are particularly relevant in geometry learning because geometric concepts are closely connected to objects and situations encountered in daily life.

More broadly, the findings of this study are relevant to the continuing challenge of low mathematical literacy among Indonesian students, as reflected in the PISA 2022 results, which placed Indonesia 71st among 81 participating countries with a mathematics score of 366. These results indicate that the primary challenge in mathematics education extends beyond procedural mastery and concerns students' ability to apply mathematical knowledge in authentic contexts. Consequently, instructional approaches that promote collaboration, reflection, and deep understanding should be introduced from the elementary school level. This interpretation is emphasized the importance of students' emotional engagement and readiness in developing mathematical literacy. Similarly, that mathematical literacy helps students develop logical, critical, and creative thinking by connecting mathematical concepts to contextual problems (Apriliyanti et al., 2024). Therefore, the superior performance of students at SD Negeri 09 Pontianak Barat compared with those at SD Negeri 17 Pontianak Kota provides empirical evidence that lesson study-based mathematics instruction with a deep learning approach can enhance students' mathematical literacy more effectively than conventional instruction. The effectiveness of this approach appears to stem from its emphasis on exploration, reflection, collaboration, and contextual application of mathematical concepts rather than solely on content delivery and procedural practice.

Implications

The findings of this study provide important theoretical and practical implications for mathematics education, particularly in efforts to enhance mathematical literacy among elementary school students. From a theoretical perspective, the study contributes to the growing body of literature by demonstrating that the integration of lesson study and a deep learning approach can serve as an effective instructional framework for fostering mathematical literacy. The findings support the view that mathematical literacy develops more effectively when students are actively engaged in meaningful, contextual, and reflective learning experiences rather than merely practicing procedural skills. The study also reinforces the importance of combining student-centered pedagogical approaches with collaborative teacher professional development models to improve learning outcomes. From a practical perspective, the results suggest that elementary school teachers should consider incorporating deep learning principles into mathematics instruction to encourage students to understand, apply, and interpret mathematical concepts in authentic situations. The lesson study process provides teachers with opportunities to collaboratively design learning activities, anticipate students' difficulties, and continuously

improve instructional practices based on classroom evidence. As a result, classroom learning can become more responsive to students' needs and more conducive to the development of higher-order thinking skills. The findings further indicate that mathematical literacy can be strengthened through instructional activities that emphasize exploration, discussion, reflection, and contextual problem-solving. For school administrators, the results highlight the importance of supporting collaborative professional learning communities that facilitate lesson study implementation as part of continuous instructional improvement efforts. At the policy level, the findings suggest that educational stakeholders should promote instructional innovations that integrate deep learning and collaborative teaching practices to address the persistent challenges of mathematical literacy identified in national and international assessments. Furthermore, the successful implementation of this approach on the topic of two-dimensional shapes indicates its potential applicability to other mathematical topics and grade levels. Ultimately, the study provides empirical evidence that lesson study-based mathematics instruction with a deep learning approach represents a promising strategy for creating more meaningful mathematics learning environments and improving students' readiness to apply mathematical knowledge in real-world contexts.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting the findings. First, the research was conducted in only two public elementary schools in Pontianak City, which may limit the generalizability of the findings to other educational contexts, regions, or student populations. Second, the study focused exclusively on fourth-grade students and the topic of two-dimensional shapes, thereby restricting the applicability of the results to other grade levels and mathematical content areas. Third, the intervention was implemented over a relatively short period consisting of two instructional sessions, which may not have been sufficient to capture the long-term effects of lesson study-based mathematics instruction with a deep learning approach on students' mathematical literacy development. Fourth, the study employed a nonequivalent posttest-only control group design, which did not allow for direct measurement of students' prior mathematical literacy abilities before the intervention. Fifth, the mathematical literacy assessment relied primarily on multiple-choice items, which may not have fully captured students' reasoning processes, mathematical communication, and higher-order thinking skills. In addition, qualitative data were limited to classroom observations, field notes, and lesson study reflections, which may not have provided a complete understanding of students' learning experiences and perceptions. Therefore, future studies are encouraged to involve larger and more diverse samples from different geographical regions and educational settings to improve the external validity of the findings. Future research should also examine the implementation of lesson study-based mathematics instruction with a deep learning approach across various mathematical topics, grade levels, and school types. Longitudinal studies are recommended to investigate the sustainability of students' mathematical literacy development over extended periods of instruction. Furthermore, future researchers may consider employing pretest–posttest experimental designs and incorporating qualitative methods such as interviews, focus group discussions, or student learning journals to obtain a deeper understanding of the learning process. Finally, future investigations should explore the relationships among mathematical literacy, critical thinking, problem-solving skills, self-regulated learning, and student motivation to provide a more comprehensive understanding of how lesson study and deep learning contribute to mathematics learning outcomes.

CONCLUSION

This study shows that lesson study-based mathematics instruction using a deep learning approach yields better results than conventional instruction in terms of the mathematical literacy skills of fourth-grade students at public elementary schools in Pontianak City regarding plane figures. This is evidenced by the results of the Mann-Whitney U test, which yielded a significance value of 0.000 less than 0.05 indicating a significant difference in mathematical literacy skills between the experimental and control groups. Additionally, the effect size calculation of 0.3189 indicates that the implementation of this learning method has a moderate effect, with the learning process occurring in a structured, collaborative, and reflective manner. As seen through the plan, do, and see stages, there was an improvement in quality from the first session to the second, as well as an increase in students' ability after the learning process to understand, formulate, apply, and interpret mathematical concepts in a more contextual manner. Thus, the integration of lesson study and deep learning has proven effective in encouraging students to think more actively, critically, and meaningfully when solving everyday mathematical problems.

AUTHOR CONTRIBUTIONS STATEMENT

Ahmad Yani T served as the lead author, initiating the research idea, developing the research concept and methodology, providing supervision during the research process, and drafting the initial manuscript. Akbar Ramadhan, Hery Sutrisno, and Dyan Hayuningtrisna Hadiwangsa contributed to the research implementation, data collection and management, and the initial analysis of the research results. Dona Fitriawan contributed to refining the scientific content of the manuscript, analyzing and interpreting the results, editing and critically reviewing the manuscript, adjusting the format according to journal guidelines, managing correspondence with the journal, and finalizing and submitting the manuscript for publication. All authors have read, reviewed, and approved the final version of the manuscript, and are responsible for the content and integrity of the published research..

REFERENCES

Akın, A. (2022). The effectiveness of web-based mathematics instruction (WBMI) on K–16 students' mathematics learning: A meta-analytic research. Education and Information Technologies, 27(6), 8015–8040. https://doi.org/10.1007/s10639-022-10931-x

Almarashdi, H. S., & Jarrah, A. M. (2023). Assessing tenth-grade students' mathematical literacy skills in solving PISA problems. Social Sciences, 12(1). https://doi.org/10.3390/socsci12010033

Apriliyanti, I., T, A. Y., Siregar, N., & Meldi, N. F. (2024). Peran literasi matematika dan pembelajaran berbasis masalah terhadap kemampuan pemecahan masalah siswa. J-PiMat: Jurnal Pendidikan Matematika, 6(2), 1509–1520. https://doi.org/10.31932/j-pimat.v6i2.3934

Barokah, N., & Mahmudah, U. (2025). Transformasi pembelajaran matematika SD melalui deep learning: Strategi untuk meningkatkan motivasi dan prestasi. Bilangan: Jurnal Ilmiah Matematika, Kebumian dan Angkasa, 3(3), 48–61. https://doi.org/10.62383/bilangan.v3i3.521

Bolstad, O. H. (2023). Lower secondary students' encounters with mathematical literacy. Mathematics Education Research Journal, 35(1), 237–253. https://doi.org/10.1007/s13394-021-00386-7

Çakıroğlu, Ü., Güler, M., Dündar, M., & Coşkun, F. (2024). Virtual reality in realistic mathematics education to develop mathematical literacy skills. International Journal of Human-Computer Interaction, 40(17), 4661–4673. https://doi.org/10.1080/10447318.2023.2219960

Cao, Y., Zhang, S., Chan, M. C. E., & Kang, Y. (2021). Post-pandemic reflections: Lessons from Chinese mathematics teachers about online mathematics instruction. Asia Pacific Education Review, 22(2), 157–168. https://doi.org/10.1007/s12564-021-09694-w

Chen, W. (2025). Problem-solving skills, memory power, and early childhood mathematics: Understanding the significance of the early childhood mathematics in an individual's life. Journal of the Knowledge Economy, 16(1), 1–25. https://doi.org/10.1007/s13132-023-01557-6

Chen, Y.-C., & Techawitthayachinda, R. (2021). Developing deep learning in science classrooms: Tactics to manage epistemic uncertainty during whole-class discussion. Journal of Research in Science Teaching, 58(8), 1083–1116. https://doi.org/10.1002/tea.21693

Dahroni, D., Saputra, Z. A., Restiani, H., Ayu, M., & Pratiwi, R. H. (2025). Perbandingan efektivitas pembelajaran deep learning dan diferensiasi terhadap kemampuan pemecahan masalah dan penalaran matematika siswa SMP. Aljabar: Jurnal Ilmuan Pendidikan, Matematika dan Kebumian, 1(3), 124–140. https://doi.org/10.62383/aljabar.v1i3.683

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. Applied Developmental Science, 24(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Dibaba, T. Y., Hunde, A. B., Faith, M., & Wedajo, A. L. (2025). Enhancing mathematics teachers' professional learning engagement through lesson study in secondary schools. Journal of Workplace Learning, 38(1), 57–72. https://doi.org/10.1108/JWL-08-2025-0252

Dolapcioglu, S., & Doğanay, A. (2022). Development of critical thinking in mathematics classes via authentic learning: An action research. International Journal of Mathematical Education in Science and Technology, 53(6), 1363–1386. https://doi.org/10.1080/0020739X.2020.1819573

Ezeamuzie, N. O., Leung, J. S. C., Garcia, R. C. C., & Ting, F. S. T. (2022). Discovering computational thinking in everyday problem solving: A multiple case study of route planning. Journal of Computer Assisted Learning, 38(6), 1779–1796. https://doi.org/10.1111/jcal.12720

Fauzan, A., Harisman, Y., Yerizon, Y., Suherman, S., Tasman, F., Nisa, S., Sumarwati, S., Hafizatunnisa, H., & Syaputra, H. (2024). Realistic mathematics education (RME) to improve literacy and numeracy skills of elementary school students based on teachers' experience. Infinity Journal, 13(2), 301–316. https://doi.org/10.22460/infinity.v13i2.p301-316

Feriyanto, F., & Anjariyah, D. (2024). Deep learning approach through meaningful, mindful, and joyful learning: A library research. Electronic Journal of Education, Social Economics and Technology, 5(2), 208–212. https://doi.org/10.33122/ejeset.v5i2.321

Fox, A., & Poultney, V. (2020). Teacher professional learning through lesson study: Teachers' reflections. International Journal for Lesson and Learning Studies, 9(4), 397–412. https://doi.org/10.1108/IJLLS-03-2020-0011

Glazewski, K. D., & Ertmer, P. A. (2020). Fostering complex problem solving for diverse learners: Engaging an ethos of intentionality toward equitable access. Educational Technology Research and Development, 68(2), 679–702. https://doi.org/10.1007/s11423-020-09762-9

Hervas, G., & Medina, J. L. (2020). Key components of lesson study from the perspective of complexity: A theoretical analysis. Teachers and Teaching, 26(1), 118–128. https://doi.org/10.1080/13540602.2020.1745174

Ingram, N., Holmes, M., Linsell, C., Livy, S., McCormick, M., & Sullivan, P. (2020). Exploring an innovative approach to teaching mathematics through the use of challenging tasks: A New Zealand perspective. Mathematics Education Research Journal, 32(3), 497–522. https://doi.org/10.1007/s13394-019-00266-1

Jansen, S., Knippels, M.-C. P. J., & van Joolingen, W. R. (2021). Lesson study as a research approach: A case study. International Journal for Lesson and Learning Studies, 10(3), 286–301. https://doi.org/10.1108/IJLLS-12-2020-0098

Ji, Y. (2023). The effect of teacher engagement factors on teachers' lesson study professional development in Chinese school settings. International Journal for Lesson and Learning Studies, 12(4), 273–287. https://doi.org/10.1108/IJLLS-01-2023-0015

Jiang, R. (2022). Understanding, investigating, and promoting deep learning in language education: A survey on Chinese college students' deep learning in the online EFL teaching context. Frontiers in Psychology, 13. https://doi.org/10.3389/fpsyg.2022.955565

Kelly, S., & Abruzzo, E. (2021). Using lesson-specific teacher reports of student engagement to investigate innovations in curriculum and instruction. Educational Researcher, 50(5), 306–314. https://doi.org/10.3102/0013189X20982255

Koskinen, R., & Pitkäniemi, H. (2022). Meaningful learning in mathematics: A research synthesis of teaching approaches. International Electronic Journal of Mathematics Education, 17(2). https://doi.org/10.29333/iejme/11715

Kovač, V. B., Nome, D. Ø., Jensen, A. R., & Skreland, L. L. (2025). The why, what and how of deep learning: Critical analysis and additional concerns. Education Inquiry, 16(2), 237–253. https://doi.org/10.1080/20004508.2023.2194502

Kundu, A., Bej, T., & Rice, M. (2021). Time to engage: Implementing math and literacy blended learning routines in an Indian elementary classroom. Education and Information Technologies, 26(1), 1201–1220. https://doi.org/10.1007/s10639-020-10306-0

Lazić, B. D., Knežević, J. B., & Maričić, S. M. (2021). The influence of project-based learning on student achievement in elementary mathematics education. South African Journal of Education, 41(3), 1–10. https://doi.org/10.15700/saje.v41n3a1909

Lai, C.-P., Zhang, W., & Chang, Y.-L. (2020). Differentiated instruction enhances sixth-grade students' mathematics self-efficacy, learning motives, and problem-solving skills. Social Behavior and Personality: An International Journal, 48(6), 1–13. https://doi.org/10.2224/sbp.9094

Lewis, C., & Perry, R. (2017). Lesson study to scale up research-based knowledge: A randomized, controlled trial of fractions learning. Journal for Research in Mathematics Education, 48(3), 261–299. https://doi.org/10.5951/jresematheduc.48.3.0261

Manfreda Kolar, V., & Hodnik, T. (2021). Mathematical literacy from the perspective of solving contextual problems. European Journal of Educational Research, 10(1), 467–483. https://doi.org/10.12973/eu-jer.10.1.467

McPhail, G. (2021). The search for deep learning: A curriculum coherence model. Journal of Curriculum Studies, 53(4), 420–434. https://doi.org/10.1080/00220272.2020.1748231

Nilimaa, J. (2023). New examination approach for real-world creativity and problem-solving skills in mathematics. Trends in Higher Education, 2(3), 477–495. https://doi.org/10.3390/higheredu2030028

Olivares, D., Lupiáñez, J. L., & Segovia, I. (2021). Roles and characteristics of problem solving in the mathematics curriculum: A review. International Journal of Mathematical Education in Science and Technology, 52(7), 1079–1096. https://doi.org/10.1080/0020739X.2020.1738579

Öz, T., & Işık, A. (2024). The opportunities for mathematical reasoning skills that teachers provide for their students in the learning environment. Participatory Educational Research, 11(3), 1–21. https://doi.org/10.17275/per.24.31.11.3

Pellegrini, M., Lake, C., Neitzel, A., & Slavin, R. E. (2021). Effective programs in elementary mathematics: A meta-analysis. AERA Open, 7, 2332858420986211. https://doi.org/10.1177/2332858420986211

Polman, J., Hornstra, L., & Volman, M. (2021). The meaning of meaningful learning in mathematics in upper-primary education. Learning Environments Research, 24(3), 469–486. https://doi.org/10.1007/s10984-020-09337-8

Rahmawati, S. (2022). Kemampuan guru dalam mengimplementasikan model pembelajaran lesson study mata pelajaran matematika di tingkat madrasah tsanawiyah. JEID: Journal of Educational Integration and Development, 2(3), 172–186. https://doi.org/10.55868/jeid.v2i3.142

Sakurai, J., & Goos, M. (2023). Revisiting tools in numeracy learning: The role of authentic digital tools. Frontiers in Education, 8. https://doi.org/10.3389/feduc.2023.1291407

Salinas-Navarro, D. E., Vilalta-Perdomo, E., Michel-Villarreal, R., & Montesinos, L. (2024). Using generative artificial intelligence tools to explain and enhance experiential learning for authentic assessment. Education Sciences, 14(1). https://doi.org/10.3390/educsci14010083

Seleznyov, S. (2019). Lesson study: Exploring implementation challenges in England. International Journal for Lesson and Learning Studies, 9(2), 179–192. https://doi.org/10.1108/IJLLS-08-2019-0059

Simin, S., T, A. Y., & Bistari, B. (2022). Literasi matematis siswa sekolah menengah atas dari struktur kognitif pada konsep limit fungsi. Jurnal Cendekia: Jurnal Pendidikan Matematika, 6(1), 48–57. https://doi.org/10.31004/cendekia.v6i1.1112

Spencer, M., Fuchs, L. S., Geary, D. C., & Fuchs, D. (2022). Connections between mathematics and reading development: Numerical cognition mediates relations between foundational

competencies and later academic outcomes. Journal of Educational Psychology, 114(2), 273–288. https://doi.org/10.1037/edu0000670

Suh, J., Matson, K., Seshaiyer, P., Jamieson, S., & Tate, H. (2021). Mathematical modeling as a catalyst for equitable mathematics instruction: Preparing teachers and young learners with 21st century skills. Mathematics, 9(2). https://doi.org/10.3390/math9020162

Sulaiman, R., & Mansyur, U. (2024). Pembelajaran berdiferensiasi berbasis lesson study untuk meningkatkan hasil belajar siswa. Jurnal Riset dan Inovasi Pembelajaran, 4(3), 2246–2257. https://doi.org/10.51574/jrip.v4i3.2364

Sumliyah, S., Junaedi, I., & Mulyono, M. (2025). Mathematical literacy: A comparative analysis of school mathematics curricula in Indonesia, Singapore, and China. Jurnal Inovasi Matematika, 7(1), 105–129. https://doi.org/10.35438/inomatika.v7i1.488

Surtika, W., & U.S, S. (2024). Studi literatur tentang peningkatan kemampuan literasi matematika pada model pembelajaran problem based learning. STRATEGY: Jurnal Inovasi Strategi dan Model Pembelajaran, 4(4), 120–126. https://doi.org/10.51878/strategi.v4i4.3557

Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. Sustainability, 12(23). https://doi.org/10.3390/su122310113

Tian, Y., Zhao, X., & Huang, W. (2022). Meta-learning approaches for learning-to-learn in deep learning: A survey. Neurocomputing, 494, 203–223. https://doi.org/10.1016/j.neucom.2022.04.078

Torres-Peña, R. C., Peña-González, D., Lara-Orozco, J. L., Ariza, E. A., & Vergara, D. (2025). Enhancing numerical thinking through problem solving: A teaching experience for third-grade mathematics. Education Sciences, 15(6). https://doi.org/10.3390/educsci15060667

Vale, I., & Barbosa, A. (2023). Active learning strategies for an effective mathematics teaching and learning. European Journal of Science and Mathematics Education, 11(3), 573–588. https://doi.org/10.30935/scimath/13135

Weng, C., Chen, C., & Ai, X. (2023). A pedagogical study on promoting students' deep learning through design-based learning. International Journal of Technology and Design Education, 33(4), 1653–1674. https://doi.org/10.1007/s10798-022-09789-4

Ye, H., Liang, B., Ng, O.-L., & Chai, C. S. (2023). Integration of computational thinking in K–12 mathematics education: A systematic review on CT-based mathematics instruction and student learning. International Journal of STEM Education, 10(1), 3. https://doi.org/10.1186/s40594-023-00396-w

Zeng, C. (2025). The effects of students' backgrounds, attitudes, and ICT familiarity on mathematical literacy: Latent profile analysis and lasso regression. Education and Information Technologies, 30(5), 5451–5475. https://doi.org/10.1007/s10639-024-13028-9

Zhang, J.-H., Zou, L., Miao, J., Zhang, Y.-X., Hwang, G.-J., & Zhu, Y. (2020). An individualized intervention approach to improving university students' learning performance and interactive behaviors in a blended learning environment. Interactive Learning Environments, 28(2), 231–245. https://doi.org/10.1080/10494820.2019.1636078