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AN EXAMINATION OF HOW PROBLEM-BASED LEARNING INFLUENCES THE MATHEMATICAL LITERACY CAPABILITIES OF MIDDLE SCHOOL STUDENTS, ANALYZED THROUGH THE LENS OF LEARNING PREFERENCES

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ABSTRACT

Mathematical literacy is an essential competency that enables students to apply mathematical knowledge and reasoning to solve problems encountered in everyday life. However, students' mathematical literacy skills remain relatively low, indicating the need for instructional approaches that promote meaningful learning. This study aimed to examine the effectiveness of the Problem Based Learning (PBL) model in improving students' mathematical literacy skills, to determine the effect of learning styles on mathematical literacy skills, and to investigate the interaction between the PBL model and learning styles. This study employed a quantitative approach using a quasi-experimental method with a pretest–posttest control group design. The participants were seventh-grade students of SMPN 1 Bontolempangan selected through cluster random sampling. The experimental group consisted of 34 students who were taught using the Problem Based Learning (PBL) model, while the control group consisted of 33 students who received conventional instruction. Data were analyzed using a two-way analysis of variance (Two-Way ANOVA) at a significance level of 0.05. The findings revealed that the Problem Based Learning (PBL) model had a significant positive effect on students' mathematical literacy skills ($p < 0.001$). In contrast, learning styles did not have a statistically significant effect on students' mathematical literacy skills ($p = 0.649$). Furthermore, no significant interaction was found between the learning model and learning styles in influencing students' mathematical literacy skills ($p = 0.308$). In conclusion, the Problem Based Learning (PBL) model is more effective than conventional instruction in improving students' mathematical literacy skills. However, students' learning styles do not significantly influence mathematical literacy achievement, nor do they moderate the effectiveness of the learning model.

Keywords: Problem Based Learning, Proficiency in Mathematics, Individual Approaches to Learning, Systems of Linear Equations Involving A Single Unknown Variable

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PRELIMINARY

Student performance in mathematics serves as a significant metric for evaluating educational system quality across numerous nations, Indonesia included. Proficiency in mathematics extends beyond conceptual understanding; it encompasses logical reasoning, adeptness at problem-solving, and the capability to integrate mathematical principles into diverse practical scenarios (OECD, 2022). Within the framework of contemporary education in the 21st century, mathematical literacy has become an increasingly important competency because it integrates the understanding of mathematical concepts with critical thinking skills required to face the challenges of modern society and the world of work (Sudianto & Ramdiani, 2024). revious investigations have shown that a significant proportion of students have not yet developed the reasoning capabilities needed to successfully solve mathematics problems presented in authentic, real-world situations, even though they have participated in mathematics learning for a considerable period of time (Sudianto & Ramdiani, 2024).

The report of the Academic Ability Test (TKA) in 2025 released by the Ministry of Primary and Secondary Education indicates that students' mathematical competence at the senior high school level and its equivalent remains relatively low. The national average mathematics score only reached 36.10 out of a maximum score of 100.00. This low achievement was consistently observed across various types of secondary education institutions, including general senior high schools (SMA) with an average score of 37.23, vocational high schools (SMK) with 34.74, and Islamic senior high schools (MA) with 35.72. These findings indicate that students' mathematical abilities have not yet reached the expected competency standards, highlighting the need for improvements in the mathematics learning process in schools (Kemendikdasmen, 2025).

The low level of students' mathematics achievement has become a serious concern for various stakeholders, including The education sector in Indonesia is overseen by Commission X of the House of Representatives (DPR RI)**.** Commission X of the DPR RI considers the results of the 2025 TKA as an important warning for the education sector to conduct a comprehensive evaluation of the national learning process, including aspects of instructional strategies, curriculum implementation, and the improvement of teachers' competencies through continuous professional development programs (Lalu Hadrian Irfani, 2025). To enhance students' learning experiences in mathematics, educators can employ instructional methods that emphasize active participation, independent inquiry, and the development of critical and analytical thinking skills necessary for solving complex problems.

However, the effectiveness of a learning model is not solely determined by the instructional approach applied by teachers but is also influenced by students' individual characteristics, one of which is learning style. Learning style refers to an individual's tendency to receive, process, and understand information during the learning process (Barbe, Swassing, & Milone, 1979 in DePorter & Hernacki, 2016). Previous studies have shown that the alignment between instructional strategies and students' learning styles can affect learning outcomes, including mathematics learning achievement (Zain et al., 2023). Yudistira, Syaiful, and Anggareini (2020) investigated the implementation of the Problem-Based Learning (PBL) model and the role of verbal-visual abilities as factors influencing students' mathematics learning outcomes through a quasi-experimental study involving eighth-grade students. The findings revealed that the implementation of the PBL model had a significant positive effect on students' mathematics learning outcomes ($p = .001 < .05$). In addition, students' verbal-visual abilities significantly influenced their learning outcomes ($p < .001$), indicating that learning characteristics contribute to academic achievement. However, the study found no significant interaction between the PBL model and verbal-visual abilities ($p = .341 > .05$), suggesting that the effectiveness of PBL was consistent across students with different verbal-visual abilities. Similarly, Arni, Kosim, and Verawati (2024) examined the effect of the Problem-Based Learning model on students' learning outcomes based on visual, auditory, and kinesthetic learning styles using a quasi-experimental pretest-posttest nonequivalent control group design. Their findings showed that students who learned through the PBL model achieved significantly higher posttest scores than those who received conventional instruction, demonstrating that PBL effectively enhanced students' conceptual understanding and problem-solving skills. Furthermore, learning styles significantly influenced students' learning outcomes, indicating that differences in learning preferences contributed to variations in academic achievement. Nevertheless, no significant interaction was found between the PBL model and learning styles, suggesting that although both variables independently affected students' learning outcomes, learning styles did not moderate the effectiveness of the PBL model. Collectively, these studies demonstrate that the implementation of Problem-Based Learning consistently improves students' learning outcomes, while learning characteristics or learning styles serve as independent factors influencing academic achievement rather than altering the effectiveness of the instructional model (Yudistira et al., 2020; Arni et al., 2024).

Although previous studies have examined the implementation of the Problem-Based Learning (PBL) model and the role of learning styles as factors influencing students' learning outcomes, research that investigates the interaction between the PBL model and learning styles on students' mathematical literacy skills remains limited, particularly in the context of Indonesian junior high schools. This indicates a research gap regarding how the effectiveness of the PBL model may vary based on students' learning style preferences. Therefore, this study aims to analyze the effect of the PBL model on students' mathematical literacy skills and to examine differences in mathematical literacy among students with different learning styles. The findings of this study are expected to provide valuable contributions to the development of effective mathematics learning strategies that are responsive to students' characteristics and support innovation in mathematics teaching practices (Agustin et al., 2022).

METHODS

The investigation was conducted using a quantitative research method and This study employed a quasi-experimental design, as this approach enables the investigation of the effectiveness of Problem-Based Learning (PBL) in enhancing students' mathematical literacy, while also considering differences in learning styles that might influence the results. According to Creswell (2018), quasi-experimental research is an appropriate design for educational contexts in which researchers cannot conduct full randomization of research subjects because students are already organized into administratively formed classes.

The research study employed a 2 × 3 factorial design involving two instructional approaches and three learning style categories. The instructional approaches consisted of n this study, the experimental group was taught using the Problem-Based Learning (PBL) model, while the control group received conventional instruction. In addition, students were categorized into three learning styles: visual, auditory, and kinesthetic. Arends (2012) explains that a factorial design allows researchers to analyze the influence of several independent variables on a dependent variable at the same time, as well as to identify possible interactions among them. Therefore, this design offers a broader and more detailed perspective on the relationships among the variables under investigation. The layout of the research design is illustrated in the table below.

Table 1. Research Design

Learning Model	**Visual (B_1)**	**Auditory (B_2)**	**Kinesthetic (B_3)**
PBL Model (A_1)	A_1B_1	A_1B_2	A_1B_3
Control Model (A_2)	A_2B_1	A_2B_2	A_2B_3

All students enrolled in Grade VII at SMP Negeri 1 Bontolempangan for The demographic for this investigation comprised all students enrolled in the 2024/2025 academic session. This cohort encompassed 112 individuals distributed across four concurrently running classes. From these four classes, a sample was curated by selecting two distinct groups. One group was identified as the experimental cohort and engaged with instructional content presented via the Problem-Based Learning (PBL) methodology. The other group served as the control cohort. and was taught using conventional instructional practices.

The sampling technique used was cluster random sampling, which involves selecting samples randomly based on existing groups or classes rather than individual students (Fraenkel et al., 2019). The sampling procedure was conducted by writing the names of the four classes on separate pieces of paper, followed by a random draw to select two classes as the research sample. A second random draw was then conducted to determine which class would serve as the group assigned to the experimental condition, while the other group functions as the control condition According to Ary et al. (2019), cluster random sampling is an efficient and practical technique for educational research because it does not disrupt the existing classroom structure and is easier to implement than individual randomization.

A pretest was conducted before the intervention to evaluate the initial mathematical literacy levels of students in both groups and to confirm their comparability. By establishing that the groups were equivalent at baseline, any subsequent differences in posttest performance could be interpreted as the result of the treatment administered (Shadish et al., 2002).

Providing varying levels of difficulty aims to identify students' mathematical literacy ability across different cognitive levels, from basic skills to higher-order thinking skills. The test is scored using a holistic rubric, with each item being rated on a scale ranging from 0 to 4, which is then converted to a 0–100 scale to facilitate interpretation of the results.

The test instrument was validated through expert judgment by mathematics education experts and was also pilot-tested to examine its validity and reliability before being used in the research (Arikunto, 2013). The results are presented in the following table.

Table 2. Validity Test Results

Item	rxy	rtable	Criteria	Interpretation
1	0.930	0.374	Valid	Very High
2	0.916		Valid	Very High
3	0.778		Valid	High

All items have r-count values greater than r-table at a 5% significance level, indicating that the items are valid (Priyanto, 2020). Mathematical literacy test items must be contextual, non-routine, and require a mathematization process from real-life situations into mathematical models in order to measure students' abilities in the three aspects of mathematical literacy according to the PISA framework, namely formulate, employ, and interpret. The development of the test instrument was adjusted to the learning material of grade VII junior high school and adapted to the characteristics of internationally validated PISA items (OECD, 2019).

The results of the reliability test are shown below.

Table 3. Reliability Test Result

Item	Reliability Degree	Criteria	Interpretation
5	.824	Reliable	High

Results from the reliability assessment demonstrated that the mathematical literacy test attained a coefficient of 0.824. This value signifies that the instrument is highly reliable, as it is capable of providing consistent and stable measurements across its administration.

Table 4. Difficulty Level Test Results

Item	Difficulty Index	Criteria
1	0.625	Moderate
2	0.438	Moderate
3	0.098	Difficult

According to the difficulty index analysis, items 1 and 2 fall into the medium category, while item 3 is categorized as difficult. The analysis of research data consisted of two sequential stages, namely the examination of baseline data obtained from the pretest and the evaluation of outcome data derived from the posttest. To confirm that the data satisfied the necessary assumptions, the pretest scores were first analyzed using normality, homogeneity, and mean comparison tests. Similarly, the posttest scores were assessed through normality and homogeneity testing before hypothesis verification was conducted using a two-way analysis of variance (ANOVA). All statistical procedures and he computations were performed using IBM SPSS Statistics version 25.

Non-test data were collected using a learning style questionnaire develoved based on the VARK model proposed by Fleming and Baume (2006). The questionnaire consists of 30 statements using a Likert scale of 1–5, where 10 items measure The questionnaire consisted of 30 items, including 10 items assessing visual learning styles, 10 items measuring auditory learning styles, and 10 items evaluating kinesthetic learning styles.

According to Alqahtani and Al-Gahtani (2022), the VARK instrument has been proven to be valid and reliable in identifying students' learning style preferences in various learning contexts, including mathematics learning. Each statement describes students' preferences in receiving and processing information during learning activities, with the Participants were provided with the following answer options:

1 : strongly
2 : Disagree
3 : Neither Agree Nor Disagree
4 : Agree
5 : Strongly Agree

Students are categorized Based on the highest score obtained in one of the three learning style dimensions, calculated by summing the scores for each dimension (maximum score per dimension = 50).

The learning style questionnaire used in this study has undergone validity testing using Pearson product moment correlation, This indicates that all items have calculated r-values exceeding the r-table value of 0.361 at the 5% significance level, confirming their validity. indicating that they are valid (Priyanto, 2020). Furthermore, An examination of the instrument's reliability using the Cronbach's Alpha approach demonstrated that it attained a coefficient value of $\alpha = 0.847$, which falls into the high reliability category ($\alpha \geq 0.70$), indicating that the instrument consistently measures students' learning style constructs (Nunnally & Bernstein, 1994).

The data in this study were collected through a series of procedures. First, a learning style questionnaire was given to all students in both the experimental and control groups to determine the distribution of their learning styles before the treatment was applied.

Data were analyzed using descriptive and inferential statistic prosedures. Desvriptive statistics served to summarize the characteristics of students' mathematical literacy scores across both groups by examining measures of central tendency and dispersion, while also providing information regarding the distribution of learning styles within each group.

RESULT AND DISCISSION

This study employed a quasi-experimental design involving an experimental class and a control class. The experimental class received instruction using the Problem-Based Learning (PBL) model, while the control class received expository learning. The learning material used in both classes was the System of Linear Equations in One Variable (SPLSV), which included the concepts of linear equations, solving procedures, and application of SPLSV problems in real-life contexts.

The research was conducted through four learning meetings in each class. Before the treatment, students were given a pretest to identify their initial mathematical literacy abilities. After the learning process, a posttest was administered to measure students' mathematical literacy skills after receiving different instructional treatments. In addition, students' learning styles were identified using a learning style questionnaire consisting of visual, auditory, and kinesthetic categories.

The classification of students' learning styles was obtained from the analysis of questionnaire responses. The results showed that the experimental class consisted of 34 students, while the control class consisted of 33 students. Based on the overall classification, the visual learning style was the most dominant category, with 27 students, followed by kinesthetic and auditory learning styles. These findings indicate that students in both classes had diverse learning style characteristics.

Description of Initial Ability Analysis

Before analyzing the effect of the learning model, students' initial abilities were examined through pretest scores. The analysis included normality, homogeneity, and independent sample t-test. The Shapiro-Wilk normality test showed that the pretest data of the experimental class obtained a significance value of 0.073, while the control class obtained 0.079. Since both values were greater than 0.05, the pretest data were considered normally distributed.The homogeneity test using Levene's test resulted in a significance value of 0.492, indicating that the variance of the pretest scores between the experimental and control classes was homogeneous. Furthermore, the independent Sample Two-Way ANOVA produced a significance value of 0.966, indicating that there was no significant difference between the initial mathematical literacy abilities of the two groups. Therefore, both classes had comparable initial abilities before the treatment was implemented. as in the following table

Table 5. Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
0.478	1	58	0.492

Posttest data were analyzed using normality, homogeneity, and two-way ANOVA tests. The normality test is shown in the following table:

Table 6. Normality Test of Posttest Data

Statistic	df	Sig.
Experimental	0.937	0.297
Control	0.953	0.297
Visual	0.934	0.297
Auditory	0.942	0.352
Kinesthetic	0.939	0.316

Table 6. states that All Sig. values are well above 0.05, meaning the posttest data for all groups (experimental and control) and all learning style categories (visual, auditory, kinesthetic) are normally distributed. This satisfies the normality assumption required for Two-Way ANOVA, so you can proceed to the homogeneity test (Levene's Test) and then the ANOVA itself without normality concerns.

The results of the homogeneity test are shown in the following table:

Table 7. Homogeneity Test of Posttest Data

	Levene Statistic	df1	df2	Sig.
Based on Mean	1.977	5	63	0.084
Based on Media	1.546	5	63	0.175

From Table 7 above, it can be observed that the significance values based on both the mean and the median are greater than 0.05. The analysis revealed no significant difference in the variances of the posttest mathematical literacy scores between the two groups, indicating that the data met the assumption of homogeneity. Once this requirement was fulfilled, the hypotheses were evaluated using a two-way analysis of variance (ANOVA).

After conducting the Normality Test and Homogeneity Test and the data shows that the prerequisites for the Two-Way ANOVA test meet the parametric requirements, the test is continued to the Two-Way ANOVA test, namely in Table 11.

Table 8. Hypothesis Test

Source	Type III Sum of Squares	df	Mean Square F	Sig
Learnig Model	3975.452	1	3975.452	33.491
Learning Style	0.000 103.212	2	51.606	0.435
Learnig Model*Learnig Style	0.649 285.145 0.308	3	142.572	1.201

Table 8 shows a two-way ANOVA analysis to examine the effect of learning models, learning styles, and the interaction between learning models and learning styles on students' mathematical literacy skills. The analysis shows that the learning model variable obtained a significance value of 0.000 ($p < 0.05$). Therefore, the null hypothesis is rejected, indicating that there is a significant difference in students' mathematical literacy skills between students who learned through the PBL model and students who learned through expository learning. Students who received PBL instruction showed better mathematical literacy performance compared to students who received conventional instruction. This finding is consistent with Agustin et al. (2022) and Astuti (2020), who reported that PBL is effective in improving students' mathematical literacy skills.

The effectiveness of the Problem Base Learning approach is also grounded in Vygotsky's constructivist theory, which maintains that knowledge is developed through meaningful social interactions. Therefore, PBL is designed to facilitate teamwork and discussion, enabling students to learn from one another while jointly working toward solutions to the problems they encounter.

The results of hypothesis testing demonstrated that H_0 was maintained due to the significance value of 0.649 for the learning style variable, which exceeded the predetermined alpha level of 0.05. Therefore, no significant variation in mathematical literacy skills was observed among students with different learning style preferences. This outcome implies that learning styles may not be a determining factor in students' mathematical literacy performance, and other variables could have a greater influence. Differences in the ways students prefer to learn constitute the first factor affecting the results. Himmah & Nugraheni (2023) explain that each class has a varied composition of learning styles with different proportions, as found in this study. The second factor relates to the teacher's instructional approach, which may not always be able to accommodate all students' learning style preferences simultaneously. The third factor is the presence of other variables outside learning styles that influence students' mathematical literacy skills but were not examined in this study. These variables include differences in students' learning motivation, family environment conditions, and the level of parental support.

The findings may have been influenced by several practical challenges experienced during the research process. One notable issue was the break in learning activities caused by the school holiday, which affected students' continuity of learning and required a period of readjustment before regular instruction could resume effectively. Consequently, students needed additional time to regain attention and engagement in classroom activities. This interpretation is supported by study conducted by Nurazizah et al. (2023), which suggested that the learning environment and surrounding conditions can have a significant impact on students' concentration levels. Hypothesis testing demonstrated that the interaction between the learning model and learning style was not statistically significant, as reflected by a significance value of 0.308, which exceeded the threshold of 0.05. Therefore, the effect of the instructional model on students' mathematical literacy skills was not dependent on differences in learning styles. Various factors may help explain this non-significant interaction effect.

First, the learning strategies implemented tend not to facilitate all types of students' learning styles simultaneously. Second, the implementation of the PBL model with LKPD provided a different learning experience for students because they were previously rarely involved in group discussions and problem-solving activities through discovering relevant information. This created high enthusiasm and interest among students toward mathematics due to the novelty of the learning approach used. This condition supports the findings of Prastika (2020), The findings emphasize the crucial role of learning interest in the learning process. Greater interest encourages students to become more actively involved in learning, enhances their ability to understand instructional content, and supports the development of effective problem solving skills in mathematics.

The findings of the third hypothesis have several implications for educational practice. The first implication is increased learning flexibility, indicating that the PBL model is adaptive and can be applied to students with diverse learning styles. A less favorable implication is the restricted potential for differentiated instruction. Because the effectiveness of the PBL model does not appear to vary across learning style categories, the learning experience may not be specifically adjusted to address the distinct needs and characteristics of individual students. The third hypothesis findings carry important implications for instructional practice. The results suggest that the PBL model can be implemented effectively across students with varying learning style preferences, reflecting its adaptability as a teaching approach. However, because no significant interaction was identified between the learning model and learning styles, the model may have limited capacity to provide individualized learning experiences that accommodate the specific needs of each learner. mathematical literacy skills based on learning styles

CONCLUSION

This study concludes that the Problem-Based Learning (PBL) model significantly improves students' mathematical literacy skills compared with conventional instruction. The effectiveness of PBL is attributed to its emphasis on active learning, collaborative problem-solving, and meaningful knowledge construction, which aligns with Vygotsky's constructivist theory. In contrast, learning styles did not have a significant effect on students' mathematical literacy skills, and no significant interaction was found between the learning model and learning styles. These findings indicate that the effectiveness of PBL is consistent across students with different learning style preferences. Therefore, PBL can be considered an effective instructional approach for enhancing students' mathematical literacy skills and may be implemented broadly to support meaningful mathematics learning.

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