THE EFFECTIVENESS OF THE PROBLEM-BASED LEARNING (PBL) MODEL ON STUDENTS' MATHEMATICAL LITERACY VIEWED FROM PRIOR KNOWLEDGE

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Abstract

This study aims to evaluate the effectiveness of the Problem-Based Learning (PBL) model on students' mathematical literacy skills in relation to their prior knowledge. The research employed a quantitative approach with a True Experimental Design, specifically the Posttest-Only Control Group design. The population consisted of all eighth-grade students at MTs Al-Munawaroh and MTs Mambaul Huda, from which the samples were selected using a Simple Random Sampling technique. A total of 94 students were involved, divided into three groups: a trial class at MTs Mambaul Huda, an experimental class (VIII B) at MTs Al-Munawaroh, and a control class (VIII A) at the same school. Data were collected through documentation and tests, and analyzed using mastery learning tests, two-way ANOVA, and right-tailed independent t-tests at a 5% significance level. The findings indicate that: (1) the experimental class taught through PBL did not fully achieve the required mastery criteria, (2) there were significant differences in mathematical literacy between students taught with PBL and those taught with conventional methods, (3) students with high prior knowledge who learned through PBL achieved better mathematical literacy compared to those in conventional classes, and (4) students with low prior knowledge also showed superior mathematical literacy outcomes when taught with PBL compared to conventional approaches.

Keywords: Problem-Based Learning (PBL); Mathematical Literacy; Prior Knowledge; Learning Effectiveness; Experimental Study.

1 INTRODUCTION

Entering the 21st century, students are expected to possess competencies and skills that enable them to face global challenges. Education is therefore required to not only transfer knowledge but also develop students' abilities in problem solving, critical thinking, creativity, collaboration, and communication. Mathematics, as one of the core subjects in schools, plays an important role in building these competencies. In particular, mathematical literacy has become an essential component, as it equips learners with the capacity to apply mathematics meaningfully in real-life contexts.

Mathematical literacy is generally understood as an individual's ability to formulate, employ, and interpret mathematics in a wide range of situations. This competency encompasses mathematical reasoning, the use of concepts, procedures, facts, and tools to describe, explain, and predict phenomena, as well as the ability to make sound decisions as an engaged, reflective citizen. For students, strong mathematical literacy not only supports academic achievement but also prepares them for future challenges in everyday life and in their professional careers.

However, in practice, many students still face difficulties in achieving adequate levels of mathematical literacy. Observations and previous studies reveal that learners often struggle to connect mathematical concepts with real-life applications, and they tend to rely heavily on rote memorization of formulas rather than developing understanding through problem-solving. This indicates that the learning approaches implemented in the classroom have not fully supported the development of students' mathematical literacy. Consequently, teachers need to adopt innovative instructional models that actively engage students in the learning process.

One instructional approach that has been widely discussed and applied is the Problem-Based Learning (PBL) model. PBL emphasizes the presentation of real-world problems as a starting point for learning, thereby encouraging students to explore, analyze, and construct solutions collaboratively. Through this process, students are trained to think critically, communicate effectively, and work together in solving contextual problems. Prior studies suggest that PBL has a positive influence on various aspects of learning outcomes, including students' mathematical literacy, problem-solving abilities, and critical thinking skills.

In addition, prior knowledge is recognized as an important factor influencing the success of mathematics learning. Students with strong prior knowledge are generally more capable of connecting new concepts with existing cognitive structures, while those with limited prior knowledge may face greater challenges in comprehension. Therefore, it is crucial to investigate the extent to which PBL can enhance students' mathematical literacy when viewed from different levels of prior knowledge.

Based on this rationale, the present study was conducted to examine the effectiveness of Problem-Based Learning (PBL) in improving mathematical literacy among students. Specifically, the study aimed to determine whether PBL is more effective than conventional teaching methods when considering students' initial ability levels. The findings of this study are expected to provide valuable insights for educators in designing mathematics learning that accommodates differences in students' prior knowledge and supports the development of mathematical literacy.

2 RESEARCH METHODOLOGY

This study employed a quantitative research approach, in which the data collected were numerical and analyzed using statistical techniques. The research design adopted was True Experimental Design, specifically the Posttest-Only Control Group design. In this design, two groups of students are selected randomly, with one group receiving treatment (experimental group) and the other not (control group). This approach was chosen to ensure the validity of comparisons between groups.

The population of this research comprised all eighth-grade students from MTs Al-Munawaroh and MTs Mambaul Huda during the first semester of the 2022/2023 academic year. The sampling technique used was Simple Random Sampling, which means that the samples were taken randomly from the population without considering class strata. Since MTs Al-Munawaroh consisted of only two classes in grade VIII, class VIII B was randomly assigned as the experimental group, while class VIII A was selected as the control group. Additionally, class VIII from MTs Mambaul Huda served as the trial group to test the instrument. In total, 94 students participated in this study.

Two data collection techniques were applied, namely documentation and tests. Documentation was used to obtain student lists and mid-semester examination (PTS) scores for mathematics. Meanwhile, the test instrument consisted of five open-ended questions designed to measure students' mathematical literacy. Prior to its use in the experimental and control classes, the instrument was piloted in a trial class at MTs Mambaul Huda. The results of the item analysis showed that all questions were valid and reliable. Based on difficulty index analysis, one item was categorized as easy, three as moderate, and one as difficult. According to the discrimination index, two items were classified as fair, two as good, and one as very good.

The data analysis process was divided into two stages: before and after the experiment. Before the experiment, equivalence tests were conducted, including normality testing using the Shapiro–Wilk test, homogeneity testing using Bartlett's test, and one-way ANOVA based on the students' mid-semester scores. After the experiment, prerequisite tests for hypothesis testing were again conducted using Shapiro–Wilk and Bartlett's tests. Once these assumptions were met, hypothesis testing was performed. The first hypothesis was analyzed using a one-sample right-tailed t-test and proportion test. The second hypothesis was tested with two-way ANOVA, while the third and fourth hypotheses were examined using independent right-tailed t-tests. All analyses were conducted at a 5% significance level.

3 RESULTS AND DISCUSSION

The analysis of the research data yielded the following findings:

Table 1. *Shapiro Wilk Normality Test.*

Class	**Statistic**	**df**	**Sign.**
Experimental	,941	32	,078
Control	,977	32	,709

Before testing the research hypotheses, prerequisite tests were conducted, namely the normality test and the homogeneity test. The Shapiro–Wilk test was employed to examine normality. As presented in Table 1, the significance value for the experimental class was 0.078 and for the control class was 0.709.

Since both significance values are greater than 0.05, it can be concluded that the mathematical literacy data from the experimental and control classes were normally distributed.

Table 2. *Bartlett's Homogeneity Test.*

	$x^2_{calculated}$	x^2_{table}	Decision
Experimental and Control Literacy	0,4709	3,841	H_0 Accepted

The results of the homogeneity test using Bartlett's method (see Table 2) indicated that the calculated chi-square value was 0.4709, which is lower than the chi-square critical value of 3.841. Based on this result, H_0 was accepted, meaning that the mathematical literacy data from both the experimental and control classes were homogeneous. Since the data from both groups met the assumptions of normality and homogeneity, further analysis could proceed to hypothesis testing.

Table 3. *Descriptive Statistics of Mathematical Literacy.*

Data	Experimental	Control
N (Students)	32	32
Mean	69,19	59,06
Median	69,5	60,5
Mode	77	54
Variance	261,90	335,22
Std. Deviation	16,18	18,31
Maximum	91	90
Minimum	37	16
Range	54	74

Table 4. *Descriptive Statistics Based on Prior Knowledge.*

Data	Experimental		Control	
	Exp. High	Exp. Low	Control High	Control Low
Mean	75,47	60	66,94	48,93
Median	77	60	67	49,5
Mode	89	48	-	54
Variance	192,04	234,50	243,47	284,38
Std. Deviation	13,85	15,31	15,60	16,86
Maximum	91	90	90	77
Minimum	42	37	32	16
Range	49	53	58	61

The results presented in Tables 3 and 4 reveal that the average mathematical literacy score of students in the experimental class, which was taught using the Problem-Based Learning (PBL) model, was higher than that of the control class, which received conventional instruction. This finding was consistent across both categories of prior knowledge, namely students with high prior knowledge as well as those with low prior knowledge.

Table 5. *One-Sample t-Test.*

	$t_{calculated}$	t_{tsble}	Decision
Experimental	1,1142	1,696	H_0 Accepted

As shown in Table 5, the calculated t-value was 1.1142, which is lower than the critical t-value of 1.696. Thus, H_0 was accepted. This indicates that the average mathematical literacy score of students in the experimental class did not meet the minimum individual mastery criterion, which was set at 66.

Table 6. *Proportion Test.*

	$Z_{calculated}$	Z_{table}	Decision
Experimental	0,2887	1,64	H_0 Accepted

As presented in Table 6, the calculated Z-value was 0.2887, which is lower than the critical Z-value of 1.64. Therefore, H_0 was accepted. This implies that the proportion of students in the experimental class whose mathematical literacy scores exceeded the mastery threshold of 66 had not yet reached the predetermined target of 60%.

Table 7. *Two-Way ANOVA.*

	$F_{calculated}$	F_{table}	Decision
Experimental vs Control Literacy	6,9765	4,0011	H_0 Rejected

The analysis of the second hypothesis using a two-way ANOVA, as presented in Table 7, showed that the calculated F-value was 6.9765, which is greater than the critical F-value of 4.0011. Based on this result, H_0 was rejected. Therefore, it can be concluded that there was a significant difference in mathematical literacy between students who were taught using the Problem-Based Learning (PBL) model and those who received conventional instruction.

Table 8. *Independent t-Test (High Prior Knowledge).*

Data	$t_{calculated}$	t_{table}	Decision
Experimental (High) vs Control (High)	1,7602	1,689	H_0 Rejected

The results of the third hypothesis test, as presented in Table 8, indicated that the calculated t-value was 1.7602, which exceeded the critical t-value of 1.689. According to the testing criteria, H_0 was rejected. This finding suggests that students who were taught using the Problem-Based Learning (PBL) model demonstrated superior mathematical literacy compared to those who received conventional instruction, particularly among the group with high prior knowledge.

Table 9. *Independent t-Test (Low Prior Knowledge).*

Data	$t_{calculated}$	t_{table}	Decision
Experimental (Low) vs Control (Low)	1,7811	1,708	H_0 Rejected

The analysis of the fourth hypothesis, as presented in Table 9, showed that the calculated t-value was 1.7811, which exceeded the critical t-value of 1.708. Based on the testing criteria, H_0 was rejected. Thus, it can be concluded that students who learned through the Problem-Based Learning (PBL) model demonstrated better mathematical literacy than those who received conventional instruction, particularly within the group of students with low prior knowledge.

Based on the implementation of the Problem-Based Learning (PBL) model at MTs Al-Munawaroh, data on students' mathematical literacy were collected from both the experimental and control groups. Prior to testing the research hypotheses, prerequisite analyses were conducted, namely the normality test using the Shapiro-Wilk method (Table 1) and the homogeneity test with Bartlett's method (Table 2). The results confirmed that the data from both groups were normally distributed and homogeneous.

The analysis of the first hypothesis was related to the mastery learning test. Referring to the results presented in Tables 5 and 6, it was revealed that the mathematical literacy of students in the experimental class taught through PBL had not yet reached the established mastery criteria, either individually or collectively. Nevertheless, the experimental group still achieved a higher mean score compared to the control group that received conventional instruction (Table 3). A similar trend was observed in Table 4, where the experimental group consistently outperformed the control group across both high and low prior knowledge categories.

This superiority can be attributed to the fact that the PBL model provides students with more meaningful learning experiences than conventional methods. Through this approach, learners are trained to develop competencies and skills via problem-solving activities that are directly relevant to real-life contexts, as emphasized by Herutomo (2020:27). Furthermore, PBL positions students as active participants in the learning process, thereby enhancing problem-solving abilities, information-seeking skills, group discussions, collaboration, mathematical communication, as well as fostering critical thinking and creativity.

The analysis of the second hypothesis (Table 7) demonstrated significant differences in mathematical literacy between students who were instructed through PBL and those taught with conventional methods. These findings are consistent with the study of Khusnul Syuhada, Suyono, and Eti Dwi Wiraningsih (2022), titled “The Effect of the PBL Model on Conceptual Understanding and Self-Esteem Viewed from Students' Initial Ability at the Junior High School Level”, which reported a significant improvement in self-esteem among students taught using PBL compared to conventional instruction. Similarly, the research of M. Farhan, Rarasaning Setianingsih, and Via Yustitia (2020), “Problem-Based Learning on Literacy Mathematics: Experimental Study in Elementary School”, confirmed significant differences in mathematical literacy between experimental and control classes. Such differences can be explained by the nature of PBL, which offers students opportunities to practice solving tasks requiring problem comprehension, modeling, and strategy selection. In contrast, conventional instruction rarely presents real-world problems as learning resources, leaving students more focused on rote memorization and mechanical application of formulas.

The findings of the third hypothesis test (Table 8) indicated that students with high prior knowledge who were taught using the PBL model demonstrated better mathematical literacy than those who learned through conventional methods. This outcome can be explained by the fact that PBL introduces contextual problems at the outset of the learning process, requiring students to collaborate in problem-solving. This process encourages them to discuss, exchange ideas, and activate prior knowledge. Consequently, students with high prior knowledge are more capable of connecting existing understanding to new problem situations, leading to deeper comprehension and enhanced mathematical literacy.

When viewed from the perspective of students with low prior knowledge, the analysis of the fourth hypothesis (Table 9) revealed that mathematical literacy in the PBL group was superior to that of the conventional group. This advantage can be attributed to the active involvement required in PBL, particularly through collaborative group discussions. In such discussions, students share ideas, exchange knowledge, and develop problem-solving strategies collectively. This interaction fosters deeper understanding, allowing even those with initially low prior knowledge to improve their mathematical literacy. In other words, the collaborative nature of PBL provides opportunities for learners to complement each other's understanding, exchange perspectives, and reinforce mathematical thinking skills.

The effectiveness of PBL also depends greatly on time management. Efficient and disciplined scheduling is essential to ensure that learning activities proceed smoothly. Additionally, teachers must consider students' prior knowledge before beginning new instruction, as it serves as a prerequisite for mastering more complex material (Siwi, 2015:74). Based on the average scores of students' mathematical literacy as well as the results of hypotheses two, three, and four, it can be concluded that the application of PBL to the topic of systems of linear equations in two variables (SPLDV) is more effective than conventional learning. This is consistent with the findings of Heka Tabun (2020), in the study “Students' Mathematical Literacy Ability in Learning with the Problem-Based Learning Model”, which confirmed that students' mathematical literacy was higher under PBL compared to non-PBL approaches. The study by Megita Dwi Pamungkas and Yesi Franita (2019), titled “The Effectiveness of Problem-Based Learning to Improve Students' Mathematical Literacy”, also supports this conclusion by showing that PBL can significantly enhance students' mathematical literacy in mathematics learning.

4 CONCLUSIONS

Based on the results of the analysis and discussion, it can be concluded that the mathematical literacy skills of students taught using the Problem-Based Learning (PBL) model have not yet fully achieved the predetermined mastery criteria. Nevertheless, their average performance was higher than that of students who received conventional instruction. Furthermore, a significant difference was identified between the two groups, indicating that students who engaged in PBL demonstrated stronger mathematical literacy compared to those taught through traditional methods, both among learners with high prior knowledge and those with low prior knowledge. Therefore, the PBL model can be considered effective for use in mathematics instruction, particularly in the topic of Systems of Linear Equations in Two Variables (SPLDV).

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