The Effectiveness of Using the Problem-Based Learning Model on Students' Understanding of Mathematical Word Problems

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Abstrak

Penelitian ini bertujuan menganalisis efektivitas model pembelajaran Problem Based Learning *(PBL) terhadap pemahaman soal cerita matematika siswa kelas VI sekolah dasar. Penelitian menggunakan metode* quasi experiment *dengan desain* nonequivalent control group. *Kelas eksperimen adalah kelas VI SD Negeri Randusari Sleman yang menerapkan PBL, sedangkan kelas kontrol adalah kelas VI SD Negeri Koroulon 2 yang menggunakan pembelajaran kontekstual. Pemilihan sampel dilakukan secara purposif dengan mempertimbangkan kesamaan karakteristik akademik dan kondisi pembelajaran. Instrumen penelitian berupa tes esai pretest dan posttest untuk mengukur pemahaman soal cerita, didukung dokumentasi. Analisis data menggunakan statistik deskriptif dan uji hipotesis* Independent Samples T-Test *setelah memenuhi uji normalitas dan homogenitas. Hasil penelitian menunjukkan bahwa siswa pada kelas PBL mengalami peningkatan pemahaman yang lebih tinggi dibandingkan kelas kontekstual. Perbedaan tersebut signifikan secara statistik, sehingga dapat disimpulkan bahwa PBL lebih efektif dalam membantu siswa memahami, menganalisis, dan menyelesaikan soal cerita secara sistematis. Model PBL direkomendasikan sebagai alternatif strategi pembelajaran matematika di sekolah dasar untuk meningkatkan kemampuan berpikir kritis dan kontekstual siswa.*

Kata Kunci: *Problem Based Learning, Pemahaman Soal Cerita, Matematika Sekolah Dasar.*

Abstract

This study aims to analyze the effectiveness of the Problem-Based Learning (PBL) learning model on the understanding of mathematical story problems of sixth-grade elementary school students. The study used a quasi-experimental design with a nonequivalent control group. The experimental class was the sixth grade of Randusari State Elementary School, Sleman, which implemented PBL, while the control class was the sixth grade of Koroulon 2 State Elementary School, which used contextual learning. Sample selection was carried out purposively by considering similarities in academic characteristics and learning conditions. The research instrument was a pretest and posttest essay test to measure understanding of story problems, supported by documentation. Data analysis used descriptive statistics and an independent samples t-test after fulfilling the normality and homogeneity tests. The results showed that students in the PBL class experienced a higher increase in understanding than those in the contextual class. The difference was statistically significant, so PBL is more effective in helping students understand, analyze, and solve story problems systematically. The PBL model is recommended as an

alternative mathematics learning strategy in elementary schools to improve students' critical and contextual thinking skills.

Keywords: Problem-Based Learning, Mathematical Word Problems, Students' Understanding, Elementary Mathematics Education.

A. Introduction

Mathematics literacy has become a major concern in both international and national educational contexts (Warniatun & Junaedi, 2020). Globally, large-scale assessments such as PISA consistently report that students struggle with solving contextual and word-based mathematical problems that require interpretation, reasoning, and the application of concepts rather than procedural recall. Mathematical word problems demand higher-order thinking skills, including analysis, representation, and evaluation (Kim How et al., 2022; Li et al., 2024). However, many students struggle to translate real-life situations into mathematical models and to determine appropriate solution strategies. This issue indicates that mathematics learning in many contexts still emphasizes procedural competence rather than deep conceptual understanding.

In the Indonesian context, similar challenges are evident. National assessments and classroom-based evaluations reveal that elementary students often show low achievement in solving story problems, particularly those involving multi-step reasoning. Students frequently misinterpret problem statements, fail to identify relevant information, or apply incorrect operations. Research indicates that these difficulties are closely related to limited reading comprehension, weak numeracy literacy, and instructional approaches that are predominantly teacher-centered (Asyifa & Sutikno, 2025; Ritonga & Zainal, 2022; Susilowati et al., 2024). These findings highlight the urgent need for instructional innovation that promotes active engagement and structured problem-solving processes.

Responding to these issues, researchers and educators have emphasized the importance of student-centered learning models. One instructional approach that has gained international recognition is Problem-Based Learning (PBL). PBL positions authentic problems as the starting point for learning and encourages students to actively investigate, analyze, and collaboratively construct solutions. A meta-analysis by Tokac et al. (2022) confirms that PBL has a significant positive effect on students' academic achievement, particularly in mathematics and science. Similarly, Yew & Goh (2020) explain that PBL promotes meaningful learning by engaging students in inquiry processes that foster deeper conceptual understanding.

In the Indonesian context, several studies have also reported the effectiveness of PBL in improving mathematical literacy and problem-solving skills (Qadri et al., 2023). Warniatun & Junaedi (2020) found that PBL enhances students' mathematical literacy by integrating contextual problems with collaborative inquiry. Nugroho & Riyadi (2021) reported that PBL significantly improves students' critical thinking skills in mathematics learning. Furthermore, Fitriani et al. (2023) demonstrated that students taught using PBL show better reasoning abilities compared to those experiencing conventional instruction. These studies indicate that PBL contributes positively to students' cognitive development.

In addition to PBL, Contextual Teaching and Learning (CTL) has also been widely implemented in mathematics classrooms. CTL emphasizes connecting learning materials to real-life experiences, enabling students to perceive the relevance of mathematical concepts in daily situations (Rohani et al.,

2024). Studies by Ritonga & Zainal (2022) and Yunita et al. (2024) show that CTL can improve students' engagement and contextual understanding. Comparative research by Sari et al. (2025) reveals that both PBL and CTL positively influence mathematical problem-solving ability, though the degree of effectiveness varies with classroom implementation.

Despite the growing body of literature on PBL and CTL, several gaps remain. First, many prior studies have examined mathematical literacy or general problem-solving skills without specifically examining students' comprehension of elementary-level mathematical word problems. Second, limited research directly compares PBL and CTL within similar instructional contexts using quasi-experimental designs involving intact classes from comparable schools. Third, few studies explicitly analyze how PBL contributes to students' ability to systematically interpret, analyze, and model story problems in upper elementary grades (Adnan & Anwar, 2020; Cazzola, 2021). Therefore, further empirical investigation is needed to clarify the comparative effectiveness of PBL in enhancing word problem comprehension.

Based on these gaps, this study offers several novelties. First, it specifically focuses on students' understanding of mathematical word problems, rather than general achievement or literacy. Second, it employs a quasi-experimental nonequivalent control group design involving two comparable elementary schools, allowing for a more contextualized comparison between PBL and CTL. Third, this study emphasizes the structured problem-analysis process inherent in PBL as a mechanism for improving students' interpretative and analytical skills in solving story problems. These contributions provide additional empirical evidence regarding the pedagogical value of PBL in elementary mathematics education.

Considering the persistent international and national challenges related to students' mathematical word problem comprehension, and the need for instructional models that foster critical and systematic problem-solving, this study aims to analyze the effectiveness of the Problem-Based Learning model compared to the Contextual Teaching and Learning model in improving sixth-grade students' understanding of mathematical word problems.

B. Research Method

This study employed a quasi-experimental research design with a nonequivalent control group. This design was selected because random assignment of students to experimental and control groups was not feasible, given existing class structures within schools. Quasi experimental designs are commonly used in educational research when intact classes are utilized while still allowing researchers to examine causal relationships between instructional interventions and learning outcomes (Creswell, 2019; Fraenkel et al., 2019).

The nonequivalent control group design enabled the researcher to compare the effectiveness of two instructional models Problem-Based Learning (PBL) and Contextual Teaching and Learning (CTL) by administering pretests and posttests to both groups. This design was considered appropriate for identifying differences in students' understanding of mathematical word problems arising from different learning models.

The research procedure was conducted in several systematic stages. First, a preliminary study was conducted to identify students' difficulties in understanding mathematical word problems and to assess the suitability of the learning models. Second, pretests were administered to both the experimental and control groups to assess students' initial understanding. Third, the experimental group received instruction using the Problem-Based Learning model, while the control group was taught using the Contextual Teaching and Learning model. The instructional treatment was implemented according to the respective syntax of each learning model. Finally, posttests were administered to both groups to evaluate changes in students' understanding after the intervention.

The population of this study comprised all sixth-grade students from two elementary schools in Sleman Regency, namely SD Negeri Randusari and SD Negeri Koroulon 2. The total population comprised 27 students. The sample was determined using purposive sampling, with consideration given to similarities in curriculum implementation, grade level, and general academic characteristics (Sugiyono, 2022). The experimental group consisted of sixth-grade students from SD Negeri Randusari, who were taught using the PBL model. The control group consisted of sixth-grade students from SD Negeri Koroulon 2, who received instruction using the CTL model. Thus, the experimental and control classes were drawn from different schools, a condition that supports the application of the nonequivalent control group design.

The primary research instrument was an essay test designed to measure students' understanding of mathematical word problems. The test was administered as both a pretest and a posttest. The essay format was chosen to allow students to demonstrate their ability to interpret problems, determine solution strategies, and explain their reasoning processes. The indicators used to assess students' understanding of mathematical word problems included: Identifying known and unknown information in the problem. Interpreting problem situations into mathematical representations. Selecting appropriate mathematical operations and strategies. Solving problems accurately and systematically. Explaining the solution process logically and coherently. The test items were developed in accordance with the Grade VI mathematics curriculum and validated through expert judgment to ensure content validity. Supporting instruments included observation sheets to monitor the implementation of the learning models, as well as documentation in the form of lesson plans, student worksheets, and photographs of learning activities.

Data were collected using several techniques to ensure comprehensive and reliable findings. Tests were used to obtain quantitative data on students' understanding of mathematical word problems through pretest and posttest scores. Observations were conducted during the learning process to ensure that the PBL and CTL models were implemented in accordance with their respective procedures. Documentation was collected to support and triangulate the data obtained from tests and observations.

Data analysis involved both descriptive and inferential statistical methods. Descriptive statistics were used to describe students' learning outcomes, including tendencies of improvement in understanding mathematical word problems. Prior to hypothesis testing, assumption tests were conducted, including normality tests using the *Shapiro Wilk* test and homogeneity tests using *Levene's test*. Inferential analysis was performed using the *Independent Samples T-Test* to determine whether there was a significant difference in students' understanding of mathematical word problems between the experimental and control groups. This statistical test was selected because the study compared the mean scores of two

independent groups. All data analyses were conducted using IBM SPSS Statistics software. The use of appropriate statistical procedures ensured the validity and reliability of the research conclusions (Field, 2018; Pallant, 2020)(Field, 2018; Pallant, 2020).

C. Result and Discussion

1. Result

The research process began with administering a pretest to students to determine their initial abilities before the treatment was applied to both the experimental and control groups. Prior to the intervention, the experimental class had an average pretest score of 40.58, while the control class obtained an average score of 35.60.

After the implementation of the instructional treatment PBL in the experimental class and CTL in the control class, students were given a posttest. The posttest aimed to evaluate the effectiveness of the learning models applied during the instructional process. The posttest results of the experimental and control classes are presented in Table 1.

Table 1. Comparison of Posttest Results

Class	Mean	Highest Score	Lowest Score	Score Improvement
Experimental (PBL)	83.08	98	68	42.5
Control (Contextual)	63.93	80	37	28.33

Table 1 indicates that the experimental class achieved a mean posttest score of 83.08 in mathematical word problem comprehension, with a highest score of 98 and a lowest score of 68, resulting in an average improvement of 30 points. In contrast, the control class obtained a mean score of 63.93, with the highest score of 80 and the lowest score of 37, and an average improvement of 28.33 points

Normality Test of Posttest Scores in the Experimental and Control Classes

The normality test was conducted to determine whether the data were drawn from a normally distributed population. In this study, the Shapiro–Wilk test was employed using IBM SPSS Statistics version 23. The results of the posttest normality test for both classes are presented in Table 2.

Table 2. Normality Test of Posttest Scores

Class	Kolmogorov–Smirnov Sig.	Shapiro–Wilk Sig.
Control Posttest	0.089	0.068
Experimental Posttest	0.200*	0.595

*This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Table 2 shows that the significance values of the Shapiro–Wilk test for the experimental class (0.595) and the control class (0.068) are greater than 0.05 ($p > 0.05$). Therefore, it can be concluded that the posttest data in both classes are normally distributed.

Homogeneity Test of Posttest Scores

The homogeneity test was conducted to determine whether the variances of students' scores were homogeneous across groups. The Levene's Test was applied using IBM SPSS Statistics version 23. The criterion for homogeneity in this study was a significance value greater than 0.05 ($p > 0.05$). The results of the homogeneity test are presented in Table 3.

Table 3. Homogeneity Test of Posttest Scores

Result	Levene Statistic	df1	df2	Sig.
Based on Mean	3.245	1	25	.084
Based on Median	2.503	1	25	.126
Based on Median and with adjusted df	2.503	1	22.741	.127
Based on trimmed mean	3.127	1	25	.089

The results indicate a significance value of 0.084 ($p > 0.05$), suggesting that the posttest scores of the experimental and control classes have homogeneous variances. Thus, the data meet the assumption of homogeneity.

Hypothesis Testing Using *Independent Samples T-Test*

Hypothesis testing was conducted to determine whether the PBL model was effective in improving students' comprehension of mathematical word problems. An *Independent Samples T-Test* was performed using posttest data from both classes. The results are presented in Table 4.

Table 4. Independent Samples T-Test Results

Group	N	Mean	Std. Deviation	Std. Error Mean
Control Class Posttest	15	63.93	14.190	3.664
Experimental Class Posttest	12	83.08	8.857	2.557

Based on the results of the *Independent Samples T-Test*, the significance value (*2-tailed*) was 0.000, which is less than 0.05 ($p < 0.05$). This indicates a significant difference in students' comprehension of mathematical word problems between those taught using the PBL model and those taught using the contextual learning model. Therefore, it can be concluded that the implementation of the PBL model is effective in improving sixth-grade students' comprehension of mathematical word problems at SD Negeri Randusari, Sleman.

In addition to the statistical analysis results, a qualitative examination of students' answer sheets revealed meaningful differences in performance patterns between the experimental and control groups across high, medium, and low achievement categories. Students in the high category within the experimental group demonstrated the ability to clearly identify relevant information, translate word problems into appropriate mathematical representations, apply correct operations systematically, and provide logical explanations for their solutions. In the medium category, most students were able to determine suitable strategies but occasionally made minor computational or representation errors. Meanwhile, students in the low category generally had difficulty interpreting the problem context and

selecting appropriate operations, although those in the experimental group exhibited more structured reasoning than their counterparts in the control group. In contrast, students in the control group, particularly in the medium and low categories, often relied on procedural guessing without clearly analyzing the given information, resulting in incomplete or inconsistent solution steps. These findings indicate that, beyond statistical significance, the Problem-Based Learning model contributed to improvements in the quality of students' reasoning processes and systematic problem-solving approaches across different ability levels.

2. Discussion

The results of this study demonstrate that implementing the PBL model significantly improves students' comprehension of mathematical word problems. This finding is supported by the Independent Samples T-Test results, which indicated a statistically significant difference between the experimental and control groups ($p < 0.05$). These results suggest that PBL is more effective than CTL in enhancing students' ability to interpret, analyze, and solve mathematical word problems.

The superiority of PBL can be attributed to its emphasis on student-centered learning and the use of authentic problems as the starting point for instruction. Mathematical word problems require students to translate real-life situations into mathematical representations, which aligns closely with the core principles of PBL. Recent studies indicate that PBL enhances conceptual understanding by encouraging students to actively engage in problem identification, information analysis, and solution evaluation (Sari et al., 2025; Tokac et al., 2022). This is reinforced by studies showing that PBL is effective in improving mathematics learning outcomes in elementary school students, both in grade III (Huwaidah dkk., 2025) and in grade II with the assistance of digital interactive games (Sudarwan, 2025)(Sudarwan, 2025), demonstrating the flexibility of this model across different grade levels.

Furthermore, PBL facilitates deeper cognitive processing by promoting inquiry-based learning and collaborative discussion. Through group work and guided investigation, students are encouraged to articulate their reasoning, justify their solutions, and reflect on alternative strategies. Research confirms that such learning environments significantly enhance students' reasoning and problem-solving skills, particularly in mathematics education (Yew & Goh, 2020)(Yew & Goh, 2020). Findings from classroom action research also strengthen this, where the application of PBL was shown to improve not only learning outcomes but also the critical thinking skills of fourth-grade elementary students in solving word problems, with the percentage of learning mastery increasing from 44.84% in the pre-cycle to 88.89% in cycle II (Saputri & Wardani, 2021). Additionally, PBL contributes to the gradual improvement of mathematical concept understanding, as demonstrated in a study at SD Negeri 39 Parepare in grade IV, which increased from the "sufficient" category to "very good" after the implementation of PBL (Mardiani, 2021).

Moreover, PBL facilitates deeper cognitive processing by promoting inquiry-based learning and collaborative discussion. Through group work and guided investigation, students are encouraged to articulate their reasoning, justify their solutions, and reflect on alternative strategies. Research by Yew & Goh (2020) confirms that such learning environments significantly improve students' reasoning and problem-solving skills, particularly in mathematics education.

In contrast, while the CTL model emphasizes connecting learning materials to real-life contexts, it may not sufficiently guide students through systematic problem-solving procedures. CTL focuses primarily on contextual relevance, but it does not always provide structured stages for problem analysis. As a result, students may struggle to determine appropriate mathematical operations when solving complex word problems. This limitation is reflected in the lower posttest scores obtained by the control group.

Innovations in PBL implementation also show promising results. For example, the integration of Lampung folklore comics into the PBL model was proven to have a significant effect on students' mathematical problem-solving abilities (Nurhasanah, 2025). This finding indicates that PBL can be enriched with local wisdom to increase the relevance and appeal of learning. Similarly, the use of concrete media and digital interactive games in PBL has been shown to enhance student motivation, active participation, and collaboration skills, with learning mastery increasing (Sudarwan, 2025). The problem-based approach also encourages students to realize that mathematics is not merely abstract knowledge, but a powerful tool for solving real-world problems. At the international level, this problem-based learning approach is supported by research affirming that students learn better when they actively grapple with mathematical problems, often referred to as productive struggle, which promotes long-term understanding and the development of mathematical language (Aristin dkk., 2023).

Another key factor contributing to PBL's effectiveness is its ability to enhance students' critical thinking skills. Mathematical word problems require higher-order cognitive skills, including analysis, synthesis, and evaluation. Studies conducted by Fitriani et al. (2023) and Nugroho & Riyadi (2021) demonstrate that PBL significantly enhances students' critical thinking abilities, which in turn positively impact their performance in solving word problems. The findings of this study are consistent with recent empirical research indicating that PBL positively impacts students' mathematical achievement. A meta-analysis by Tokac et al. (2022) revealed that PBL produces a moderate to strong effect on students' learning outcomes, particularly in mathematics and science subjects. Similarly, Putri & Zulkardi (2020) reported that students taught using PBL demonstrated better problem-solving skills than those taught using conventional methods.

In addition to cognitive benefits, PBL also supports the development of 21st-century skills, such as collaboration, communication, and creativity. During the PBL process, students work collaboratively to explore problems, exchange ideas, and construct solutions. According to Fonna & Nufus (2024), PBL naturally fosters these competencies, which are essential for students to adapt to the demands of modern education and future workplaces.

Despite its advantages, PBL also presents certain challenges in classroom implementation. The model requires sufficient instructional time, well-prepared learning materials, and teachers who are skilled in facilitating inquiry-based learning. Without adequate scaffolding, students may experience cognitive overload, particularly those with lower prior knowledge. This concern is supported by recent findings from Adnan & Anwar (2020), who emphasize the importance of structured guidance in problem-based environments.

However, when implemented with appropriate planning and teacher facilitation, the benefits of PBL outweigh its limitations. In this study, the use of validated learning modules, structured worksheets, and guided discussion helped ensure that students remained focused and engaged throughout the learning

process. These strategies contributed to the significant improvement observed in students' comprehension of mathematical word problems. In conclusion, this study provides strong empirical evidence that the PBL model is effective in improving students' understanding of mathematical word problems. By engaging students in active problem-solving, critical thinking, and collaborative learning, PBL enhances both conceptual understanding and motivation to learn. Therefore, PBL is highly recommended as an instructional approach for mathematics learning at the elementary school level, particularly for improving students' ability to solve word problems.

D. Conclusion

Based on the results of data analysis and discussion, it can be concluded that the PBL model is effective in improving students' comprehension of mathematical word problems. The statistical analysis, using the Independent Samples T-Test, showed a significant difference between the experimental group, taught using PBL, and the control group, taught using CTL, indicating that students who participated in PBL-oriented instruction achieved higher learning outcomes. The effectiveness of PBL is attributed to its emphasis on authentic problem-solving, active student engagement, critical thinking, and collaborative learning, which support deeper conceptual understanding of mathematics. Therefore, the PBL model is recommended as a practical instructional approach for elementary school mathematics, particularly for enhancing students' ability to analyze and solve mathematical word problems.

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