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The Effectiveness of Using Problem Based Learning-Based Student Worksheets to Improve Elementary School Students' Mathematical Problem-Solving Skills

Sattya Dewi Larasati[1a]*, Herpratiwi[2b], Caswita[3c]
[123]University of Lampung, Indonesia

[a]sattyadewilarasati@gmail.com, [b]herpratiwi64@yahoo.com, [c]caswita.1967@fkip.unila.ac.id

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***Correspondence Address:**
sattyadewilarasati@gmail.com

Abstract:
This study aims to develop Student Worksheets (LKPD) based on Problem-Based Learning (PBL) and evaluate their validity, practicality, and potential effectiveness in improving mathematical problem-solving skills of fifth-grade students. Using a pre-experimental One-Group Pretest-Posttest Design, the study involved fifth-grade students at SD Negeri 3 Kemiling Permai. Data were collected through expert validation sheets, teacher and student questionnaires, and pretest-posttest measurements targeting four Polya problem-solving indicators, then analyzed using the Paired Sample t-test and normalized gain (N-Gain) analysis. Results showed a statistically significant increase in problem-solving scores after the intervention ($p = 0.000 < 0.05$), with an average N-Gain of 0.765 ("Moderate") and an effectiveness percentage of 76.5% ("Fairly Effective"). These findings suggest that the PBL-based worksheets have potential as effective instructional scaffolding, supporting students' transition toward more active problem solvers capable of analyzing contextual problems and formulating solution strategies. However, as this study used a one-group design without a control group, the observed gains cannot be firmly attributed to the intervention alone; further studies with a control group are recommended. This study highlights the practical value of problem-centered materials in implementing the Kurikulum Merdeka..

Introduction (مقدمة)

Education plays a strategic role in determining the direction of a nation's development and progress. The quality of education is directly proportional to a country's capacity to produce superior, competent, and globally competitive human resources (OECD, 2022; World Bank, 2020). Through a structured educational process, individuals not only acquire substantive knowledge but also internalize the values, attitudes, and skills essential for self-development and contribution to social, national, and state life (Yusof, 2023).

In the 21st-century paradigm, the dynamics of education have undergone a significant shift with the rapid integration of Information and Communication Technology (ICT). This transformation demands a reorientation of educational goals to develop human resources with character through mastery.*21st Century Skills*(Puspa et al., 2023). Contemporary education no longer focuses on passive knowledge transfer, but rather on developing adaptive, creative, and innovative individuals to face the complexities of the globalization era (Hasibuan & Prastowo, 2015). Specifically, indicators of successful 21st-century education are reflected in mastery of the 4C skills, namely:*creative thinking*, *critical thinking and problem solving*, *communication*, And *collaboration*(Annisa et al., 2023; Hafild, 2025). These skills are cognitive and social foundations that must be systematically internalized in instructional activities at school.

The Indonesian government responded to this challenge by delegating the Independent Curriculum which positions students as active subjects (*active learners*) in the construction of their own knowledge (Hafild, 2025; Jiyantari et al., 2023). The approach*student-centered learning*This opens up a wide exploration space for the development of 4C skills (Indarta et al., 2022). Among these four skills, problem-solving ability (*problem-solving skill*) is the most crucial instrument because it underlies an individual's ability to adapt to complex situations, both in academic contexts and in the realities of everyday life. In the realm of elementary school mathematics education, problem-solving skills are a core competency; students are required not only to memorize mathematical algorithms, but also to be able to transform conceptual understanding into logical and structured solutions to contextual problems.

Theoretically, problem-solving is a high-level cognitive process involving problem identification, analysis of alternative solutions, and effective strategy execution (Jonassen, 2020). Greiff et al. (2019) elaborated that problem-solving is dynamic, involving metacognitive regulation and adaptation to complex situations. This definition aligns with the OECD (2021) perspective, which highlights an individual's capacity to use knowledge and experience to respond to challenges *unstructured*. Within the constructivist framework, Mayer (2022) emphasizes the importance of*schema construction*in organizing information to generate innovative solutions, while Angeli and Valanides (2023) emphasize the collaborative dimension of the process. Dewey (1998) emphasized the importance of reasoning and problem-solving as the core of active learning. Furthermore, Marzano (2001) and Vygotsky (2012) confirm that cognitive and social interactions within problem-solving contexts essentially enrich children's cognitive structures.

However, there is a fundamental gap (*gap analysis*) between curricular ideals and empirical realities in the field. Various literature shows that elementary school students' mathematical problem-solving abilities are still low, particularly in indicators of problem understanding and planning solution strategies (Barus & Hakim, 2020; Maghfiroh et al., 2021; Pratiwi & Alyani, 2022). Students often experience difficulties in defining known and questioned variables and make mistakes in executing solution procedures (Dari & Efficacy, 2024). This condition stems from the dominance of a procedural-decontextual learning paradigm that focuses on memorizing formulas (Chen et al., 2019; Szabo et al., 2020). Teachers' limited focus on designing problem-solving-based activities is a major causative factor (Damianti & Afriansyah, 2022; Izzah & Azizah, 2019), even though the development of these abilities is highly determinant of students' overall cognitive improvement (Rahmatiya & Miatun, 2020).

The empirical conditions at the research location reinforce the urgency of the problem. Based on a preliminary study test of mathematical problem-solving abilities conducted on fifth-grade students of SD Negeri 3 Kemiling Permai, it was revealed that students' problem-solving abilities were still relatively low. The percentage achievement for each indicator showed suboptimal performance, namely the indicator for understanding the problem was 45.30%, planning a solution was 37.59%, implementing the solution was 35.66%, and the indicator for reviewing the entire answer only reached 29.40%. This data confirms that the majority of students experience cognitive disruption from the initial understanding stage to the final evaluation stage. The selection of fifth-grade students of SD Negeri 3 Kemiling Permai and the subject of mathematics was based on the consideration that students at this level already have basic mathematical abilities so they are ready to participate in problem-solving-based learning that requires logical, critical, and systematic thinking.

The results of a preliminary study analysis through observations and interviews with three fifth-grade teachers at SD Negeri 3 Kemiling Permai further clarified the root of the instructional problem. The findings showed that 100% of teachers still rely entirely on government-published textbooks and have not implemented teaching materials that support the development of mathematical problem-solving skills. In addition, 67% of teachers have not actively involved students in learning, where the learning process is still dominated by teacher explanations of material and example problems on the board, followed by individual practice problems from textbooks. This phenomenon has implications for many students who receive scores below the criteria, with 67% of teachers stating this. This condition limits students' opportunities to carry out optimal problem-solving activities, such as identifying problems, analyzing information, formulating strategies, discussing alternative solutions, and evaluating results.

Based on these fundamental problems, a reorientation of learning is needed that allows students to actively engage in systematic problem-solving activities. These activities align with the characteristics of the Problem-Based Learning (PBL) model, where students are confronted with contextual problems as a starting point for conducting investigations, discussing, developing solutions, and presenting results (Rusmono, 2012). Several recent studies have shown that the consistent application of PBL has been proven to improve elementary school students' mathematical problem-solving abilities (Nurnaningsih et al., 2023; Astuti et al., 2023). Optimal PBL syntax requires the support of appropriate teaching materials in the form of PBL-based Student Worksheets (LKPD), which have proven effective in facilitating students' mathematical problem-solving at various levels (Ma'wa et al., 2021; Surya Edukasi Education Journal, 2021).

However, most research on the development of PBL-based student worksheets (LKPD) has focused on junior high and senior high school levels, and few have specifically integrated Polya's problem-solving indicators into the implementation framework of the Independent Curriculum at the elementary school level (Agusdianita et al., 2024). Research combining PBL-based LKPD development with systematic testing of its validity, practicality, and effectiveness for fifth-grade elementary school students, particularly in the context of implementing the Independent Curriculum, remains limited. This gap underpins the urgency of this research.

The results of this study are expected to provide meaningful contributions both theoretically and practically. Theoretically, this research is useful in enriching the scientific knowledge of basic education regarding the development of innovative PBL-based teaching materials that focus on the development of *21st Century Skills* and the Independent Curriculum. Practically, this research provides benefits for students by facilitating active and structured learning experiences; for educators as an alternative guide for contextual mathematics teaching materials; for schools as a means of improving the quality and availability of innovative learning resources; and for other researchers as a methodological reference or reference for developing similar research in the future.

Method (منهج)

This research is part of development research. *(Research and Development)* teaching materials in the form of Student Worksheets (LKPD) based on *Problem Based Learning* (PBL) to improve the mathematical problem-solving abilities of fifth-grade elementary school students. The product effectiveness testing stage uses a problem-solving design. *One-Group Pretest-Posttest Design* This study focuses on testing the effectiveness of using PBL-based LKPD in improving students' mathematical problem-solving abilities without using a comparison group (control class). In this design, the treatment (*treatment*) in the form of mathematics learning using PBL-based LKPD was given to a single subject group, namely fifth grade students of SD Negeri 3 Kemiling Permai. Before the treatment was given, students took an initial test (*pretest*) () to measure initial mathematical problem solving abilities. Next, a final test was conducted (*posttest*) () after the treatment is completed, it is given to measure the final achievement of students' mathematical problem solving on four main indicators (understanding the problem, planning the solution, implementing the solution, and evaluating/reviewing the answer).Mathematical problem solving ability data obtained from scores *pretest* And *posttest* analyzed quantitatively through two stages of statistical testing. First, to determine the significance of the difference in mean scores before and after treatment, a difference test was conducted using a paired t-test (*Paired Sample t-test*), after the data meets the analysis prerequisite test in the form of a normality test. Second, to measure the level of improvement in students' mathematical problem-solving abilities after utilizing PBL-based LKPD, a normalized gain score calculation is carried out (*Normalized Gain*/ N-Gain). Use of LKPD based on *Problem Based Learning* (PBL) is declared effective if there is a statistically significant increase in mathematical problem solving scores between *pretest* And *posttest*, and the average N-Gain value is at the minimum criteria of "moderate" or "effective".

Result (نتائج)

1. Data Normality Test

The normality test was conducted to determine whether the research data followed a normal distribution. In this study, the normality test was performed using the Shapiro-Wilk test via SPSS software, given that the sample size was fewer than 50 subjects. The significance level applied was $\alpha = 0.05$, with the decision rule stating that if the significance value (Sig.) is greater than 0.05 (Sig. > 0.05), the data are normally distributed. The results of the normality test are presented in Table 1.

Table 1. Normality Test Results

Class/Test	Shapiro-Wilk (Sig.)	Decision
Pretest	0.113	Normal
Posttest	0.175	Normal

Based on Table 1, the obtained Sig. value for the pretest data is 0.113, which exceeds the significance threshold (0.113 > 0.05). Similarly, the Sig. value for the posttest data is 0.175, which also exceeds the threshold (0.175 > 0.05). Consequently, it can be concluded that the analyzed dataset is normally distributed.

2. Homogeneity Test

The homogeneity test was conducted to determine whether the data from the study group possessed equal (homogeneous) variances. In this study, the homogeneity test was performed using Levene's test via SPSS software at a significance level of $\alpha = 0.05$. Data are declared homogeneous if the significance value (Sig.) is greater than 0.05 (Sig. > 0.05). The results of the homogeneity test are presented in Table 2.

Table 2. Homogeneity Test Results

Parameter	Levene Statistic	df1	df2	Sig.
Based on Mean	5.038	1	58	.069
Based on Median	4.738	1	58	.044
Based on Median and with adjusted df	4.738	1	45.048	.045
Based on Trimmed Mean	5.014	1	58	.059

Based on the variance homogeneity test results presented in Table 2, the significance value (Sig.) calculated from the mean is 0.069. The statistical decision rule dictates that the data exhibit homogeneous variances if the obtained significance value exceeds the significance threshold of $\alpha = 0.05$ (Siregar, 2026). Because the obtained significance value exceeds this threshold ($0.069 > 0.05$), the null hypothesis (H_0) is accepted, confirming that the distribution of the students' mathematical problem-solving test scores has homogeneous variance.

3. Effectiveness Test

The magnitude of improvement in students' mathematical problem-solving skills before and after implementing the Problem-Based Learning (PBL)-based LKPD was analyzed using the Normalized Gain (N-Gain) test. This analysis aims to provide a substantive, quantitative representation of instructional treatment effectiveness, unconfounded by students' baseline entry levels (Savin-Baden & Major, 2023). Based on the data analysis results presented in Appendix 23, the mean N-Gain score achieved was 0.765. Referring to Hake's N-Gain interpretation criteria, this value ($g > 0.70$) falls into the "High" category. Furthermore, the percentage N-Gain score of 76.5% falls within the ≥ 76% range, classifying the intervention within the "Effective" criterion (Meltzer & Thornton, 2022).

Having fulfilled the prerequisite assumptions of normality and homogeneity, the parametric requirements for executing a paired-sample t-test were satisfied. This test aims to evaluate whether a statistically significant difference exists between pretest and posttest scores within the target group. The paired-sample t-test was executed using SPSS software. The complete analytical output is provided in Appendix 26, while the summarized test results are presented in Table 3.

Table 3. Paired-Sample t-Test Results

Pair	Paired Differences: Mean	Paired Differences: Std. Deviation	Paired Differences: Std. Error Mean	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper	t	df	Sig. (2-tailed)
Pretest – Posttest Learning Outcomes	-61.800	19.45	2.511	-66.825	-56.775	-24.609	59	.000

Based on the inferential hypothesis test results presented in Table 3, the two-tailed significance value (Sig.) obtained is 0.000. Statistical decision-making was conducted by evaluating the obtained significance value against the standard alpha level of $\alpha = 0.05$. Because the significance value is less than the alpha threshold (Sig. < 0.05, $p < .001$), the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted. This confirms a statistically significant difference between students' pretest and posttest mean scores in mathematical problem-solving ability following the instructional intervention utilizing Problem-Based Learning (PBL)-based LKPD.

Discussion (مناقشة)

Fulfilling this normality assumption has a very crucial methodological position in quantitative data analysis. A normal data distribution indicates that the distribution of students' mathematical problem-solving scores does not experience any deviations (*skewness*) extreme, so the average value (*mean*) obtained is able to accurately represent the centralization of population data (Gani, 2026). Fulfillment of this normality assumption provides theoretical and statistical justification for continuing inferential analysis using parametric statistical tests (Siregar et al., 2024). Thus, hypothesis testing to measure the effectiveness of the intervention before and after treatment is feasible to be analyzed using a paired t-test (*Paired Sample t-test*) and normalized gain calculations (*N-Gain*).

Meeting the homogeneity of variance assumption has crucial methodological implications for ensuring the validity of research inferences. Uniform variance indicates that cognitive variability among students is within a relatively balanced dispersion range, so that differences in scores are not influenced by unequal initial group variances (Siregar et al., 2024). Meeting this homogeneity assumption—along with meeting the previous normality assumption—provides a solid validation basis for applying parametric statistical analysis (Gani, 2026). Thus, the data are deemed to meet the formal statistical prerequisites for proceeding to inferential hypothesis testing to objectively measure the effectiveness of treatment interventions.

Theoretically and pedagogically, the improvement in mathematical problem-solving abilities within this high criterion proves that PBL-based student worksheet intervention has a significant positive impact on students' cognitive reconstruction. The characteristics of PBL-based student worksheets, which present contextual problems, are able to guide students through the problem-solving stages systematically—starting from defining problem variables, formulating strategic hypotheses, carrying out calculations, and re-evaluating the solutions obtained (Rahmadani & Prasetyo, 2024). The use of student worksheets as a learning aid *scaffolding* facilitate the role of students as active learning subjects (*active learners*), in line with the demands of the Independent Curriculum (Kusuma & Yuliani, 2023).

The N-Gain score that reaches the High () or Very Effective () category indicates that there is room for optimization in the instructional process. Students' cognitive barriers in the indicator of evaluating answers and initial adaptation to the paradigm *problem-centered learning* is suspected to be a driving factor in the less than optimal cognitive achievement of some students (Lestari et al., 2025). Methodologically, these results confirm the success of developing PBL-based LKPD teaching materials in stimulating mathematical problem-solving skills in elementary schools, while also providing a basis for recommendations for educators to strengthen*s caffolding* in the flow of student self-evaluation in subsequent implementation.

Based on the results of the inferential hypothesis test presented in the table above, a significance value of . Statistical decision making is carried out by comparing the significance value obtained to the real level . Therefore, the value (), is rejected and accepted. This statistically confirms that there is a significant difference in the average score between *pretest* And *posttest* on students' mathematical problem solving abilities after intervention with LKPD based on *Problem Based Learning* (PBL).

This rejection provides strong empirical evidence that the use of PBL-based LKPD has been proven to significantly improve the mathematical problem-solving abilities of fifth-grade students at SD Negeri 3 Kemiling Permai. The results of this paired t-test strengthen the findings of the previous test.*N-Gain*previously (or), which is in the categoryHigh And Very Effective. Integration of PBL syntax into LKPD media provides a structure*scaffolding*which guides students from the initial understanding of the problem to the stage of reconstructing mathematical solutions in a directed manner (Rahmadani & Prasetyo, 2024; Savin-Baden & Major, 2023). This confirmation of significance proves that systematically designed teaching material interventions not only improve numerical scores superficially, but also significantly stimulate conceptual changes and cognitive independence of students in solving contextual problems (Kusuma & Yuliani, 2023; Lestari et al., 2025). This development research aims to produce teaching materials in the form of Student Worksheets (LKPD) based on*Problem Based Learning*(PBL) that is valid, practical, and effective in improving the mathematical problem-solving abilities of fifth-grade students at SD Negeri 3 Kemiling Permai. Testing the effectiveness of this teaching material was conducted through a pre-experimental design (*One-Group Pretest-Posttest Design*), where the cognitive achievements of students are measured before (*pretest*) and after (*posttest*) implementation of mathematics learning based on PBL LKPD.

Based on empirical analysis before treatment, the initial condition of students' mathematical problem-solving abilities was still very low. This is reflected in the achievement *pretest* In Polya's four problem-solving indicators that have not yet reached the completion criteria: understanding the problem at 45.30%, planning a solution at 37.59%, implementing the solution at 35.66%, and reviewing the answer (evaluation) at only 29.40%. This low initial achievement is rooted in the conventional teacher-centered learning pattern (*teacher-centered*), where students are merely passive recipients of information and trained in a procedural-decontextual manner without being accustomed to exploring contextual problems (Barus & Hakim, 2020; Chen et al., 2019). The limited availability of contextual teaching materials causes students to experience cognitive disruption, especially when transforming verbal problems into mathematical models and evaluating the correctness of solution procedures (Dari & Efficacy, 2024; Pratiwi & Alyani, 2022).

In order to overcome these cognitive barriers, intervention is provided through the implementation of LKPD based on*Problem Based Learning*. The LKPD that was developed does not just contain a collection of practice questions, but is designed as an instrument *scaffolding*which guides students through the stages of problem solving in a structured manner. The PBL syntax integrated into the LKPD is oriented towards reconstructing the role of students into active learners (*active learners*) who independently orientate themselves to problems, organize learning, conduct individual and group investigations, develop and present work, and analyze and evaluate the problem-solving process (Kodariyati & Astuti, 2016; Rusmono, 2012).

Theoretically, the effectiveness of PBL-based LKPD can be explained through Vygotsky's social constructivism framework and Dewey's theory of meaningful learning. In mathematics learning, problem solving is a complex cognitive process that requires the manipulation of cognitive schemas (*schema construction*) to organize contextual information into structured solutions (Mayer, 2022). The use of PBL-based LKPD provides instructional assistance (*scaffolding*) on *Zone of Proximal Development*(ZPD) of students, enabling them to bridge the gap between their actual abilities and their potential for higher-level problem-solving (Vygotsky, 2012). Students who initially struggled to identify what was known and what was questioned became more focused because the LKPD provided visual guidance and intuitive investigative syntax (Septiani et al., 2022).

This improvement in contextual understanding aligns with the findings of Ernawati (2017) and Sukmarwati et al. (2019), who confirmed that presenting authentic problems early in learning can stimulate students' cognitive drive to think critically, logically, and analytically. Through PBL-based student worksheets (LKPD), students are gradually trained not to rush into calculations but to first analyze the relationships between variables in the problem. This has a direct impact on increasing achievement in the indicator for planning and implementing mathematical solutions (Rahmadani & Prasetyo, 2024).

The most severe cognitive obstacles faced by students are still concentrated on Polya's fourth indicator, namely evaluating or looking back (*looking back*) the answers that have been obtained (Lestari et al., 2025). Many students tend to feel satisfied after finding the final result without re-verifying the suitability of the solution to the context of the initial problem. In addition, the transition process from a passive learning paradigm to an active learning paradigm is*student-centered learning*requires a long time to adapt to metacognitive regulation for fifth grade elementary school students (Greiff et al., 2019; Jonassen, 2020).

Overall, the findings of this study confirm that the development of LKPD based on*Problem Based Learning*able to provide real solutions to the problems of mathematics learning in elementary schools. The developed teaching materials successfully facilitate students' needs for active, contextual learning, and oriented towards mastering 21st-century skills (*21st Century Skills*), especially in the domain of critical thinking and problem solving (*critical thinking and problem solving*) as mandated in the Merdeka Curriculum (Hafild, 2025; Indarta et al., 2022)

Conclusion (خاتمة)

The development of Problem-Based Learning (PBL)-based Student Worksheets (*Lembar Kerja Peserta Didik* / LKPD) has consistently proven to meet substantive feasibility criteria—valid, practical, and effective—in reconstructing fifth-grade elementary students' mathematical problem-solving capabilities. The success of this intervention is reflected in statistically significant differences in cognitive achievement ($p < .001$) between pre- and post-treatment, yielding a substantively high improvement magnitude (N-Gain = 0.765; effectiveness rate = 76.5%). Broadly, integrating PBL syntax into the LKPD structure functions effectively as a scaffolding instrument that transforms students' procedural-passive mindsets into analytical-systematic reasoning, particularly across indicators of problem comprehension, strategy formulation, and contextual solution execution.

Implicatively, these findings confirm that providing instructional materials grounded in authentic problems serves as a critical determinant in operationalizing the mandates of the *Kurikulum Merdeka* and 21st-century skills (4C) at the elementary school level. This product offers practical recommendations for educators and school policymakers to adopt problem-solving-oriented instructional resources as a viable alternative to the limitations of conventional textbooks. For future researchers, it is recommended to extend this study utilizing a Quasi-Experimental Design across a broader population scale, while incorporating enhanced metacognitive scaffolding to optimize student performance during the self-evaluation (*looking back*) phase.

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