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Improving elementary school students' mathematical problem-solving skills: The effectiveness of realistic mathematics education with problem-based learning

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Abstract
Mathematics education in Indonesian elementary schools faces significant challenges in developing students' problem-solving skills, as evidenced by the 2022 PISA results, which showed that only 18% of Indonesian students achieved the minimum proficiency level, far below the OECD average. This study aims to evaluate the effectiveness of integrating the Realistic Mathematics Education (RME) approach with Problem-Based Learning (PBL) to enhance fourth-grade students' mathematical problem-solving skills in Bekasi Regency. A quasi-experimental design with a nonequivalent control group was employed, involving 52 students selected through cluster random sampling. The experimental class received RME-based PBL instruction, while the control class received PBL instruction based on the scientific approach. Data were collected using a validated problem-solving essay test and analyzed using descriptive and inferential statistics, including independent-samples t-tests and normalized gain scores. The results demonstrated that the RME-PBL approach significantly improved students' problem-solving skills across all measured aspects: problem identification, formulation, strategy application, and result explanation. Notably, 92% of students in the experimental class achieved good or very good categories, compared to only 22.22% in the control class. The normalized gain for the experimental class was 0.81 (high category), substantially higher than the control class's 0.41 (moderate category). It is concluded that the RME-PBL approach is significantly more effective than the scientific-PBL approach in enhancing elementary students' mathematical problem-solving abilities.

Keywords: realistic mathematics education; problem-based learning; mathematical problem-solving skills; elementary school; quasi-experimental

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I. Introduction

Mathematics education in Indonesian elementary schools, particularly in Bekasi Regency, faces significant challenges in developing students' problem-solving abilities due to persistent teacher-centered approaches. (Hasyanah, Sukmaningthias, & Nuraeni, 2023) observe that mathematics learning often fails to actively engage students, with teachers providing information without presenting problems, resulting in passive knowledge acquisition. The Realistic Mathematics Education (RME) approach, which connects mathematical concepts to students' daily experiences, offers a promising solution. As noted by Daulay, Yustinaningrum, Pasaribu, Manurung, & Putri (2025), the mathematics learning process is often considered a failure in actively involving students and emains teacher-centered, with educators providing information without introducing problems, leading to passive knowledge reception. Implementing the Realistic Mathematics Education (RME) approach, which connects mathematical concepts to students' daily experiences, has been shown to effectively enhance engagement and problem-solving skills, offering a viable solution to this issue. Research demonstrates RME's effectiveness in improving engagement and problem-solving skills (Tumangger, Khalil, & Prahmana, 2024). Despite the 2013 Curriculum's emphasis on active learning, implementation remains limited, with students relying heavily on procedural memorization rather than conceptual understanding. Zuhriyah (2024) confirmed RME's significant impact, showing a large effect size (Cohen's d = 0.98) in improving mathematical connections. This local challenge reflects national trends, as evidenced by Indonesia's 2022 PISA results, where only 18% of students achieved minimum proficiency in mathematics, compared to the OECD average of 69%, and virtually none reached advanced problem-solving levels (OECD, 2023).

Research by Cahyaningsih & Nahdi (2020) indicates that the critical mathematical thinking skills of elementary school students in Indonesia remain relatively low. The theoretical foundation for addressing this challenge lies in the Realistic Mathematics Education (RME) approach, the implementation of which has been proven to significantly enhance students' critical thinking and mathematical problem-solving abilities compared to conventional learning. This effectiveness is further amplified when RME is integrated with innovative learning media such as digital comics, which can present real-world problem contexts visually and engagingly, thereby empirically demonstrating a significant positive influence on improving students' mathematical problem-solving skills (Hasyanah et al., 2023). Recent empirical studies have substantiated this approach, with meta-analyses confirming RME's significant positive effects on students' mathematical problem-solving skills across diverse cultural contexts Miharja, Bulayi, Viet, & Triet (2024) specifically demonstrating that RME enhances problem-solving through real-world contexts and visual aids relevant to students' lives. Umi et al. (2020) found that the RME-PBL integration substantially improves elementary students' problem-solving abilities while fostering independent learning and mathematical literacy. Furthermore, Nurhidayah & Yahya (2023) demonstrated that the Project-Based Blended Learning model, which shares RME's contextual approach, significantly improved students' mathematics learning outcomes in the Merdeka Curriculum implementation. This synergy between RME's contextual grounding and PBL's inquiry-based structure provides a comprehensive pedagogical model well-suited to address Bekasi's specific educational challenges while meeting global competency demands.

Elementary school students are generally at the concrete operational stage of cognitive development according to Piaget's theory. This stage is characterized by students' ability to understand concepts through tangible objects and direct experiences. The Realistic Mathematics Education (RME) approach effectively utilizes real-world contexts and everyday problems to build students' mathematical understanding (Sutarni & Aryuana, 2023). In this context, learning approaches that integrate concrete manipulatives and exploratory activities have proven effective in enhancing mathematical understanding. Recent studies emphasize the importance of aligning teaching approaches with students' cognitive development stages to achieve optimal learning outcomes, particularly in mathematics (Jadidah, Annisah, Anggilin, & Melinda, 2023; Korompis, 2023). A recent quasi-experimental study further confirmed that the RME approach significantly enhances primary school students' problem-solving skills and critical thinking abilities compared to traditional methods (Amir, Firdaus, & Pada, 2024). Additionally, a study by Umar & Zakaria (2022) found that manipulative media-based RME significantly improved elementary students' mathematical problem-solving abilities, with average scores increasing from 35.00 to 84.20 and completeness rates rising from 8% to 92%.

RME and PBL are two empirically proven approaches that can improve students' problem-solving abilities. RME encourages students to connect mathematical concepts with real-world contexts, making them easier to understand and relevant to their lives. The implementation of RME can be strengthened by using digital media, such as e-comics, to present contextual problems that are more engaging and visually appealing to students (Yulaichah, Mariana, & Wiryanto, 2024). Meanwhile, PBL provides students with opportunities to actively and independently solve problems, thereby developing critical and reflective thinking skills. Recent research indicates that implementing open-ended problem-based RME is highly effective in enhancing elementary school students' understanding and problem-solving skills (Widodo, Santia, & Katminingsih, 2023; Khotimah & Mahmudah, 2021). Furthermore, a study by Fitriani & Fauzi (2024) demonstrated that integrating PBL and RME significantly improved elementary students' critical thinking skills in mathematics, with the average score increasing from 37.7 (low category) in the pre-cycle to 82.17 (very high category) in cycle II.

Based on recent research, the integration of RME and PBL into digital teaching materials has also shown significant improvements in students' conceptual understanding and mathematical reasoning. For example, the use of RME-based activity sheets with a calendar context in LCM material has been shown to help students understand concepts through concrete, contextual visualization (Firsta, Meryansumayeka, Susanti, & Zulkardi, 2024). On the other hand, the development of interactive RME-based e-modules for parallel lines and angles not only improved students' mathematical reasoning by 38% but also validated the effectiveness of this approach in independent learning (Scristia, Herman, Sholihat, & Sari, 2024). Meanwhile, PBL-based worksheets on relations and functions material were also shown to be valid and practical in supporting students' conceptual understanding through solving real-world problems (Pratiwi Ilma, Putri, & Hiltrimartin, 2024). These findings confirm that both RME and PBL, especially when supported by digital media, can complement each other to create meaningful, student-centered learning experiences. Furthermore, a study by Meltzer (2002) suggests that students' pre-instruction mathematical skills are significantly correlated with their conceptual learning gains in physics, highlighting the foundational role of mathematics in science education.

The persistent deficiency in students' mathematical problem-solving skills, as documented in international assessments such as PISA and national evaluations, underscores the critical need for pedagogical approaches that directly address these shortcomings. In this context, Realistic Mathematics Education (RME) emerges as a particularly relevant framework, enabling students to construct mathematical understanding through meaningful, real-world contexts that enhance conceptual understanding (Umi et al., 2020). The efficacy of RME is further demonstrated through its documented impact on developing mathematical literacy, fostering creative thinking, and promoting independent learning (Rohmah & Jupri, 2024; Maslihah, Waluya, Rochmad, Karomah, & Iqbal, 2021). When strategically combined with Problem-Based Learning (PBL), which inherently promotes active and collaborative engagement with authentic problems, the integrated approach creates a powerful pedagogical synergy. This RME-PBL combination effectively cultivates the critical, creative, and adaptive problem-solving competencies essential for navigating real-world challenges, thereby directly addressing the identified gaps in current mathematics education.

The effectiveness of the RME approach and the PBL model in improving students' mathematical problem-solving skills has been confirmed by various recent empirical studies. Research by Scristia et al. (2024) shows that the development of interactive e-modules based on RME for parallel lines and angles material improved students' mathematical reasoning skills by 38%, demonstrating the link between contextual approaches and students' logical thinking (Scristia et al., 2024). Meanwhile, Pratiwi et al. (2024) affirm that the use of PBL-based student worksheets designed for relations and functions material significantly supports conceptual understanding and problem-solving through situational approaches relevant to students' daily lives (Pratiwi et al., 2024). Similarly, a study by Amar, Usmar, & Wendah (2022) demonstrated that the use of RME-based Student Worksheets (LKPD) resulted in significantly higher learning outcomes compared to classes using Scientific-based worksheets, further validating the effectiveness of RME-based teaching materials. Furthermore, Cahyaningsih & Nahdi (2021) confirmed that RME significantly enhances elementary students' critical thinking skills compared to conventional learning.

While existing research has established the individual merits of Realistic Mathematics Education (RME) and Problem-Based Learning (PBL) in enhancing mathematical competencies, a significant gap remains in understanding their *combined* effectiveness when directly compared to established alternative approaches. Previous studies, such as those by Umi et al. (2020) and Palinussa, Dias, & Ngilawajan (2021), have demonstrated the efficacy of RME-based materials and the inclusive nature of these approaches across different student ability levels. However, these studies often lack a controlled, comparative design that isolates the specific contribution of integrating RME with PBL against other prevalent teaching methods. Furthermore, there is limited empirical evidence detailing how this combination simultaneously impacts the distinct sub-skills of problem-solving identification, formulation, strategy application, and explanation of results within a specific regional context like Bekasi Regency. It is precisely this research gap that the present study aims to address. By employing a quasi-experimental design that directly contrasts the RME-PBL model with the scientific approach (integrated with PBL), this research will provide a rigorous, comparative analysis of their effectiveness. The study is specifically designed to yield detailed insights into how the RME-PBL synergy enhances each discrete aspect of problem-solving, thereby offering a nuanced understanding that prior studies have not fully delivered.

Based on this background, which highlights the persistent challenges in developing mathematical problem-solving skills despite various pedagogical interventions, a clear research gap emerges. While both RME and PBL show individual promise, there remains a lack of empirical evidence systematically evaluating their combined effectiveness, particularly for distinct problem-solving sub-skills in the Indonesian elementary education context. Therefore, this study aims to address this void by investigating the central research question: How effective is the integrated RME-PBL approach in improving elementary school students' mathematical problem-solving skills in Bekasi Regency? To provide a comprehensive answer, this question is operationalized into specific aspects of problem-solving: (1) identifying problems, (2) formulating problems, (3) applying strategies, and (4) explaining solution results.

II. Research Methods

This study employed a quasi-experimental, nonequivalent control-group design to evaluate the effectiveness of the RME approach combined with PBL in improving elementary school students' mathematical problem-solving skills. This design was particularly relevant given the constraints of educational settings where random assignment of individual subjects was not feasible, yet it allowed for systematic comparisons between intact groups (Jacoby & Ael, 2021). To enhance methodological validity, several experimental controls were implemented: both experimental and control groups were drawn from the same school cluster with similar socioeconomic backgrounds; a pretest was administered to establish baseline equivalence in mathematical problem-solving skills; the intervention duration and total instructional time were standardized across both groups; and the same teacher delivered instruction to both classes using detailed lesson plans that clearly differentiated the RME-PBL approach from the scientific approach with PBL. Furthermore, potential confounding variables such as classroom environment and availability of learning resources were controlled by ensuring comparable facilities and materials for both groups. These measures strengthened the study's internal validity by minimizing alternative explanations for observed differences in outcomes.

The research subjects were fourth-grade students in Cluster 4, South Cikarang District, Bekasi Regency, totaling 899 students from nine elementary schools. Cluster random sampling was used to select two classes: IVD as the experimental class (25 students) and IVC as the control class (27 students). Both groups participated in a 5 week intervention comprising ten 70 minute mathematics lessons (two sessions per week). The experimental class received RME-based PBL instruction following five key stages: (1) understanding contextual problems from real-world situations, (2) formulating strategies using manipulative aids, (3) applying solutions through group work, (4) presenting and discussing findings, and (5) connecting mathematical concepts to daily life. Meanwhile, the control class implemented the scientific approach with PBL through distinct phases: (1) problem observation and questioning, (2) data collection through experimentation, (3) associating concepts through analysis, (4) communicating results, and (5) creating mathematical generalizations. This parallel implementation ensured comparable learning durations while maintaining the distinct pedagogical characteristics of each approach, thereby strengthening the validity of the comparative analysis.

The primary instrument in this study was a problem-solving skills essay test, which included two main questions with a total of 16 items. Content validity was confirmed through assessments by two mathematics education experts, and reliability was tested using Cronbach's Alpha, yielding a reliability coefficient of 0.832, indicating high consistency (Luiz, Estevam, Raponi, Felix, & Barbosa, 2022).

Data were collected through pretests and posttests for both groups. Additionally, documentation data such as student worksheets, observation sheets, and learning activity photos were collected to support the primary data analysis. The instruments were piloted beforehand to ensure feasibility and measurement effectiveness.

Data analysis was conducted through descriptive and inferential approaches. Data analysis was conducted through descriptive and inferential statistical approaches. Descriptive analysis characterized the central tendency and variability of the data using mean scores, standard deviations, and minimum and maximum values. For inferential analysis, specific statistical tests were selected based on their appropriateness for the research design and data characteristics. The Kolmogorov-Smirnov test was employed to assess normal distribution, as it is particularly effective for smaller sample sizes ($n < 50$). Homogeneity of variance across groups was verified using Levene's Test, which performs robustly even when normality assumptions are not fully met. Once parametric assumptions were confirmed, independent-samples t-tests were used to examine significant differences between

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groups, as this test offers optimal power for comparing the means of two independent groups. To quantify the magnitude of improvement, normalized gain (N-gain) scores were calculated using Hake's formula, with scores ≥ 0.7 indicating high improvement effectiveness, in line with established educational research standards (Luiz et al., 2022).

Hypothesis testing specifically addressed the four theorized components of mathematical problem-solving: identifying problems, formulating problems, applying strategies, and explaining results. Independent-samples t-tests on gain scores for each aspect were selected to provide a precise measure of differential improvement between instructional approaches. The effectiveness threshold of ≥ 0.7 for normalized gain scores was maintained as it represents a substantial improvement magnitude according to educational intervention standards (Luiz et al., 2022), ensuring a rigorous benchmark for evaluating pedagogical effectiveness.

III. Results and Discussion

Description of learning implementation

To evaluate the implementation of RME-based PBL in the experimental class, the researcher used an observation sheet to assess learning. Observations were based on five main aspects of learning reflecting RME and PBL stages. The following table summarizes the learning activities observed during the process.

Table 1. Learning activities observed

No	Learning Aspect	Activity Description	Success Indicator
1	Using real-world contexts to orient students to problems	Students read and understand two contextual problems from worksheets, then identify known and asked information.	Students can accurately write down known and asked data.
2	Using models by formulating problem-solving strategies	Students create illustrations and solution strategies using number cards, then present them in table form.	Students arrange strategic steps and present them in tables.
3	Utilizing student constructions by applying problem-solving strategies	Students apply strategies to answer questions and present their answers in bar diagrams.	Students apply strategies and present answers in diagrams.
4	Interactivity by presenting problem-solving results	Students present the results of their group discussion to peers and teachers.	Students actively participate in presentations and discussions and explain problem solutions.
5	Linking and evaluating results	Teachers and students discuss problem solutions and connect them to other concepts.	Students can conclude and relate results to prior learning.

The implementation data reveal a noteworthy finding: while the control class employing the scientific approach with PBL achieved a higher implementation percentage (92.59%) than the experimental class using RME with PBL (85.42%), the learning outcomes showed the opposite pattern of effectiveness. This apparent paradox can be explained by fundamental differences in pedagogical complexity between the two approaches. The scientific approach, with its more structured and predictable sequence of observation, questioning, experimentation, and generalization, presents fewer implementation challenges for teachers accustomed to conventional teaching methods. Its clearer procedural framework allows for more consistent execution across different classroom situations. Conversely, the RME-PBL approach demands greater pedagogical skill in facilitating open-ended inquiry, adapting to diverse student-generated solutions, and managing the unpredictable nature of authentic problem-solving discussions. The slightly lower implementation score for RME-PBL likely reflects the inherent challenges in maintaining the approach's core principles - particularly its emphasis on student-directed learning and emergent mathematical thinking - within the constraints of standard classroom settings. This interpretation suggests that implementation fidelity metrics alone may not adequately capture educational quality, as the more technically perfect implementation of the scientific approach did not translate into superior student outcomes. The findings thus highlight a crucial distinction between procedural compliance and pedagogical effectiveness in mathematics education reform.

Descriptive Analysis

Statistics of the fourth-grade students' mathematical problem-solving test results obtained from the research data are presented in the following table:

Table 2. Pretest and posttest statistics

Data Description	Control Class		Experimental Class	
	Pretest	Post-test	Pretest	Post-test
Mean	31,00	59,40	32,81	83,33
Variance	177,94	185,94	133,92	69,99
Standard Deviation	13,34	13,64	11,57	8,37
Lowest Score	5,56	25,93	9,26	66,67
Highest Score	62,96	90,74	51,85	94,44

The statistical comparison of pretest and posttest scores reveals substantial pedagogical implications for the RME-PBL approach. While both groups started with comparable baseline abilities (Control: 31.00; Experimental: 32.81), the experimental group achieved markedly higher posttest scores (83.33) compared to the control group (59.40), with a notable 23.93-point difference. This substantial gap suggests that the RME-PBL framework more effectively facilitates mathematical understanding and application. The significantly lower standard deviation in the experimental group's posttest scores (8.37 versus 13.64) further indicates that the RME-PBL approach promoted more consistent learning outcomes across diverse learners, reducing the achievement variability often seen in traditional instruction.

Table 3. Mathematical problem-solving skills percentage

Aspect	Control Class (%)		Experimental class (%)	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Identifying problems	41,05	64,20	43,67	92,00
Formulating problems	34,92	57,41	32,86	80,57
Applying strategies	25,72	59,67	30,67	85,11
Explaining results	31,00	55,93	23,60	73,60

A deeper analysis of the problem-solving sub-skills reveals both the strengths and an important area for development within the RME-PBL approach. The exceptional performance in identifying problems (92.00%) confirms RME's core strength in building robust connections between real-world contexts and mathematical structures, enabling students to discern the essence of mathematical problems in familiar situations readily.

However, the relatively lower score in explaining results (73.60%), while still substantially higher than the control group, indicates that while students can successfully solve problems, they require more structured support to articulate their thought processes and mathematical reasoning clearly in written form. This is a common phenomenon in initial implementations of RME-PBL, as the complex skill of mathematical communication often develops more slowly than the ability to identify problems or apply strategies. This finding should not be viewed as a fundamental flaw, but rather as a valuable pedagogical insight for refinement.

Moving forward, the approach could be enhanced by explicitly integrating activities such as structured "math journaling," guided peer feedback sessions, or more detailed rubrics designed to assess explanatory reasoning. This targeted scaffolding would help bridge the gap between students' conceptual understanding and their ability to communicate it effectively, thereby realizing the full potential of the RME-PBL framework.

Table 4. Score percentages in the control class

Category	Pre-test (%)	Number of Students	Post-test (%)	Number of Students
Very good (86 ≤ X ≤ 100)	0,00 %	0	3,70 %	1
Good (71 ≤ X ≤ 85)	0,00 %	0	18,52 %	5
Fair (56 ≤ X ≤ 70)	3,70 %	1	37,04 %	10
Poor (41 ≤ X ≤ 55)	18,52%	5	37,04 %	10
Very Poor (X ≤ 40)	77,78%	21	3,70 %	1

Table 5. Score percentages in the experimental class

Category	Pre-test (%)	Number of Students	Post-test (%)	Number of Students
Very good (86 ≤ X ≤ 100)	0,00 %	0	40,00 %	10
Good (71 ≤ X ≤ 85)	0,00 %	0	52,00 %	13
Fair (56 ≤ X ≤ 70)	0,00 %	0	8,00 %	2
Poor (41 ≤ X ≤ 55)	24,00%	6	0,00 %	0
Very Poor (X ≤ 40)	76,00%	19	0,00 %	0

The data in both tables show that the experimental class achieved a far greater improvement in learning outcomes than the control class. After the intervention, 92% of students in the experimental class achieved good or very good ratings, compared with only 22.22% in the control class. Conversely, most control class students remained in the fair and poor categories. This indicates that the teaching approach applied in the experimental class was more effective in improving students' mathematical problem-solving skills.

Inferential Analysis

Prerequisite Data Analysis

Before hypothesis testing, prerequisite tests, including normality and homogeneity tests, were conducted to ensure the data met the basic assumptions of statistical analysis.

The following table presents the results of normality tests for pretest, posttest, and gain scores in the control and experimental classes:

Table 6. Normality test results for pretest, posttest, and gain scores

Group	Kolmogorov Smirnov	Significance	Concl.
Pretest Control	0,134	0,200	Normal
Posttest Control	0,158	0,109	Normal
Pretest Experimental	0,151	0,119	Normal
Posttest Experimental	0,170	0,060	Normal
Gain Control	0,152	0,111	Normal
Gain Experimental	0,154	0,127	Normal

The normality test results for pretest, posttest, and gain scores in the control and experimental groups showed significance values greater than 0.05, so H_0 was accepted. This means all data were normally distributed, confirming that the normality assumption for analysis was met. The following table shows the homogeneity test results:

Table 7. Homogeneity Test Results

Data	F	Sig	Conclusion
Pretest	0,256	0,615	Homogen
Posttest	2,709	0,106	Homogen
Gain	1,871	0,178	Homogen

The table shows that the homogeneity test results for the pretest, posttest, and gain scores of fourth-grade students had p-values greater than 0.05, indicating homogeneous variances across groups. Thus, the homogeneity assumption was met.

The results of the mean difference test conducted before treatment in SPSS 23 are shown in the following table.

Table 8. Mean difference test results

Data	Class	Mean	Sig. (2-*tailed*)
Pretest Scores	Eksperimental	32,81	0,604
	Control	31,00	0,604

Based on the table, the significance value (2-tailed) of 0.604 is greater than 0.05, indicating no significant difference between the experimental and control classes in terms of initial abilities. In other words, the average pretest scores for both classes were the same in mathematical problem-solving skills.

The following gain classification table shows a significant difference between the control and experimental groups regarding student learning improvement.

Table 9. Gain classification

Gain Size (g)	Frequency/ Percentage				Interpretation
	Control		Experimental		
$g \geq 0,7$	4	14,81%	22	81,48%	High
$0,3 \leq g < 0,7$	19	70,37%	3	11,11%	Moderate
$g < 0,3$	4	14,81%	0	0,00%	Low

The following bar chart illustrates the gain classification in the control and experimental groups, divided into high, moderate, and low categories.

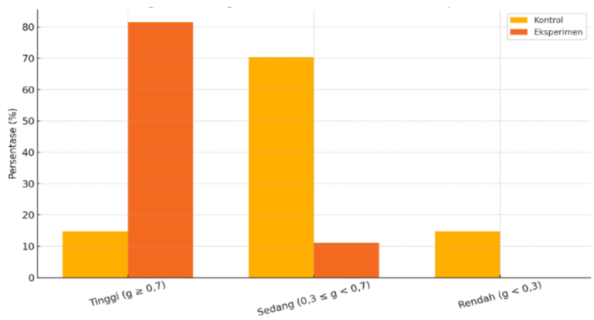

Figure 1. Bar chart of gain classification for control and experimental groups

The chart shows that the percentage of students achieving high gains was much higher in the experimental group (81.48%) compared to the control group (14.81%). Conversely, most students in the control group (70.37%) achieved only moderate gains, while the experimental group achieved only 11.11%. No students in the experimental group had low gains, whereas the control group had a 14.81% gain. This visualization reinforces the finding that the teaching approach applied in the experimental group was far more effective in improving student learning outcomes.

Research Hypothesis Testing

First Hypothesis Test

The results of the first hypothesis test are shown in the following table.

Table 10. Independent sample t-test for first hypothesis testing

Test	Mean	t-Statistic	Sig.	Conclusion
Control	8,037	- 5,206	0,000	Significant
Experimental	11,120			

The table shows the t-test results with a significance value of 0.000. Since this value is less than 0.05, H_0 is rejected, indicating a significant difference in the improvement in mathematical problem-solving skills in identifying problems between students using RME with PBL and those using the scientific approach with PBL.

Second Hypothesis Test

The results of the second hypothesis test are shown in the following table.

Table 11. Independent sample t-test for second hypothesis testing

Test	Mean	t-Statistic	Sig.	Conclusion
Control	8,037	- 5,206	0,000	Significant
Experimental	11,120			

The table shows the t-test results with a significance value of 0.000. Since this value is less than 0.05, H_0 is rejected, indicating a significant difference in the improvement of mathematical problem-solving skills in formulating problems between students using RME with PBL and those using the scientific approach with PBL.

Third Hypothesis Test

The results of the third hypothesis test are shown in the following table.

Table 12. Independent sample t-test for third hypothesis testing

Test	Mean	t-Statistic	Sig.	Conclusion
Control	10,741	- 7,112	0,000	Significant
Experimental	15,440			

The table shows the t-test results with a significance value of 0.000. Since this value is less than 0.05, H_0 is rejected, indicating a significant difference in the improvement in mathematical problem-solving skills when applying strategies between students using RME with PBL and those using the scientific approach with PBL.

Fourth Hypothesis Test

The results of the fourth hypothesis test are shown in the following table.

Table 13. Independent sample t-test for fourth hypothesis testing

Test	Mean	t-Statistic	Sig.	Conclusion
Control	5,593	- 4,062	0,000	Significant
Experimental	7,600			

The table shows the t-test results with a significance value of 0.000. Since this value is less than 0.05, H_0 is rejected, indicating a significant difference in the improvement of mathematical problem-solving skills in explaining results between students using RME with PBL and those using the scientific approach with PBL.

Based on observations of hypothesis testing and learning implementation, it was found that all aspects of students' problem-solving skills improved significantly in the experimental class. Learning was conducted through five stages of the RME-based PBL approach, starting from understanding contextual problems, modeling with number cards, group discussions, presenting results, and reflection, all of which ran smoothly. This success was reflected in students' active engagement and high learning implementation scores. These activities supported students' independent knowledge construction, aligning with the characteristics of RME, which emphasizes meaningful and contextual learning.

The superior performance of the RME-PBL approach over the scientific approach across all problem-solving sub-skills warrants critical examination beyond mere statistical superiority. While the scientific approach with PBL follows structured inquiry steps, its implementation often remains constrained by predetermined procedures that limit students' autonomous mathematical thinking. In contrast, the RME-PBL integration creates a more authentic learning environment where mathematical concepts emerge organically from contextual problems, enabling students to develop personalized solution strategies. This finding extends Umar & Zakaria's (2022) previous research by demonstrating that RME's effectiveness extends beyond manipulative media to encompass the fundamental pedagogical structure of problem-based learning. The significant gains in explaining results particularly underscore how RME-PBL transforms mathematics from a procedural exercise into a meaningful communicative activity, aligning with Freudenthal's principle that mathematics must be experienced as a human activity rather than transmitted as finished knowledge. However, the approach's effectiveness depends critically on teachers' ability to facilitate rather than direct the learning process, suggesting that implementation challenges may arise in educational contexts with a strong tradition of teacher-centered instruction. Thus, while RME-PBL offers a powerful alternative for developing conceptual understanding, its successful implementation requires substantial pedagogical shift and professional development support to achieve its full potential (Firsta et al., 2024).

The RME approach, combined with PBL, proved more effective than the scientific approach in improving students' abilities to identify problems, formulate problems, apply strategies, and explain results. This was demonstrated by the independent sample t-test results with a significance value of 0.000 (< 0.05), indicating a significant difference between the experimental and control classes. Real-world contexts in RME made it easier for students to visualize and understand problems, enabling 92% of students in the experimental class to identify them effectively. This finding aligns with the principles of RME, which emphasize the importance of contextual problems as the foundation for mathematical thinking (Mukaromah, Parmin, & Prastiti, 2023).

This study acknowledges several limitations that should be considered when interpreting its findings. First, the research was conducted in a specific geographic context (Bekasi Regency) and used relatively small sample sizes, which may limit the generalizability of the results to other educational settings. Second, the study's duration of 5 weeks, while sufficient to demonstrate initial effectiveness, does not capture the long-term sustainability of the observed improvements in problem-solving skills. Third, the implementation relied on teacher compliance with the prescribed pedagogical approaches, and variations in teaching quality, though minimized through training, could have influenced outcomes. Finally, while the instruments demonstrated good reliability, the essay tests may not fully capture all dimensions of complex problem-solving processes. Future research would benefit from longitudinal designs, larger and more diverse samples, and complementary qualitative methods to provide deeper insights into the cognitive processes underlying students' development of mathematical problem-solving.

IV. Conclusion

Based on the analysis and discussion, the use of the RME approach combined with PBL significantly enhances elementary school students' mathematical problem-solving skills in Bekasi Regency. The experimental group, which received the RME-PBL approach, showed remarkable improvements in all aspects of problem-solving, including identifying problems (92% posttest achievement), formulating problems (80.57% posttest achievement), applying strategies (85.11% posttest achievement), and explaining results (73.60% posttest achievement). These improvements were more substantial than in the control group, where only 22.22% of students reached good or very good categories after the intervention. The findings demonstrate that RME with PBL is a more effective method compared to the scientific approach, as reflected in the significant percentage gains in the experimental class, with 81.48% of students achieving high learning gains. Thus, the RME-PBL approach is a promising pedagogical strategy for enhancing elementary students' mathematical problem-solving abilities. Future research should explore the longitudinal effects of this approach across diverse educational contexts and examine specific scaffolding techniques to further enhance students' ability to explain and justify their mathematical reasoning.

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