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The Effect of Realistic Mathematics Education on Ninth-Grade Students' Mathematical Problem-Solving Ability

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Abstract
Mathematical problem-solving ability is an essential competency that supports students' Mathematical problem-solving ability is a fundamental competency in mathematics education; however, many junior high school students still experience difficulties in solving non-routine problems. This study aimed to examine the effect of the Realistic Mathematics Education (RME) approach on ninth-grade students' mathematical problem-solving ability. A quasi-experimental study employing a nonequivalent posttest-only control group design was conducted at SMPN 10 Padang during the 2025/2026 academic year. Two intact classes were selected through cluster random sampling, comprising 32 students in the experimental group and 32 students in the control group. The experimental group received instruction using the RME approach, whereas the control group received conventional instruction. Students' mathematical problem-solving ability was measured using a five-item essay test based on Polya's four problem-solving indicators. Data were analyzed using descriptive statistics, an independent-samples *t*-test, and Cohen's *d* effect size after satisfying the assumptions of normality and homogeneity. The results showed that the experimental group achieved a higher mean score than the control group (80.75 vs. 71.19). The difference was statistically significant ($t(62) = 3.46$, $p < .001$), with a large effect size ($d = 0.87$). These findings indicate that the RME approach effectively improves students' mathematical problem-solving ability and supports its implementation in secondary mathematics classrooms.

Keywords: Mathematical Problem-Solving Ability; Quasi-Experimental Study; Realistic Mathematics Education; Secondary Mathematics Education.

INTRODUCTION

Mathematical problem-solving is widely recognized as one of the most essential competencies in mathematics education because it enables students to apply mathematical knowledge, reasoning, and strategies to solve unfamiliar and real-world problems. Beyond mastering procedural skills, students are expected to analyze situations, formulate mathematical models, implement appropriate solution strategies, and evaluate the validity of their answers. Consequently, mathematical problem-solving has become a central goal of mathematics curricula worldwide and a fundamental competency for developing critical thinking, creativity, and decision-making skills required in the twenty-first century (NCTM, 2000; OECD, 2023).

Despite its importance, many students continue to experience difficulties in solving non-routine mathematical problems. International large-scale assessments consistently indicate that students perform better on routine procedural tasks than on problems requiring reasoning, modeling, and higher-order thinking. The Programme for International Student Assessment (PISA) has repeatedly reported that Indonesian students' mathematical literacy remains below the OECD average, particularly in interpreting contextual problems, selecting appropriate mathematical strategies, and evaluating solutions (OECD, 2023). These findings suggest that mathematics instruction should not merely emphasize computational procedures but should also develop students' conceptual understanding and problem-solving competence.

In Indonesia, the implementation of the *Kurikulum Merdeka* places greater emphasis on meaningful learning, higher-order thinking skills, and the application of mathematics in authentic contexts. According to the Learning Outcomes established by the Ministry of Education, Culture, Research, and Technology, mathematics instruction should enable students to understand mathematical situations, formulate mathematical models, solve problems systematically, and communicate mathematical reasoning effectively. These objectives require learning approaches that actively engage students in constructing mathematical knowledge through meaningful experiences rather than relying solely on teacher explanations and procedural practice.

One instructional approach that aligns closely with these educational goals is Realistic Mathematics Education (RME). Developed by Freudenthal (1991), RME views mathematics as a human activity that should originate from meaningful real-life situations rather than from abstract rules and formulas. Instead of directly introducing formal mathematical concepts, students are encouraged to reinvent mathematics through exploration, discussion, and reflection. Treffers (1987) further identified five fundamental characteristics of RME: the use of meaningful contexts, the transition from *model of* to *model for*, students' contributions, interactivity, and the intertwinement of mathematical concepts. Gravemeijer (1994) emphasized that these principles facilitate students' progressive mathematization by enabling them to move from informal reasoning to formal mathematical understanding. Through this process, students develop deeper conceptual understanding and stronger mathematical problem-solving abilities.

The characteristics of RME are theoretically consistent with Polya's (1973) problem-solving framework. Contextual problems help students understand mathematical situations, while model construction supports the development of solution strategies. Students' active contributions and classroom interactions encourage them to justify and evaluate different solution methods, whereas the integration of mathematical concepts promotes flexible reasoning when solving unfamiliar problems. Therefore, RME provides a strong theoretical foundation for improving mathematical problem-solving ability because it engages students in meaningful mathematical activities rather than emphasizing procedural memorization.

Previous studies have consistently reported positive effects of RME on mathematics learning outcomes. Research has shown that RME improves mathematical understanding, reasoning, communication, and problem-solving ability by encouraging students to construct mathematical concepts through contextual learning experiences (Hendriana et al., 2022; Ahmad et al., 2022; Muhaimin et al., 2024). Nevertheless, most previous studies have focused primarily on elementary school students or on general mathematics achievement. Empirical evidence examining the effectiveness of RME in improving ninth-grade students' mathematical problem-solving ability on the topic of exponents and radicals in Indonesian junior secondary schools remains limited. Furthermore, relatively few studies have explicitly operationalized the five principles of RME as the basis for instructional implementation while simultaneously evaluating students' problem-solving ability using Polya's four problem-solving indicators.

The empirical conditions observed at SMPN 10 Padang also indicate the need for instructional improvement. During the teaching practicum conducted from July to December 2025, mathematics instruction was predominantly teacher-centered. Lessons generally consisted of teacher explanations, demonstrations of worked examples, and routine practice exercises. Although students were able to imitate solution procedures, many experienced difficulties when confronted with contextual or non-routine mathematical problems requiring reasoning and strategic thinking. Instead of analyzing the problem systematically, students frequently relied on trial-and-error approaches and encountered difficulties selecting appropriate solution strategies.

To further identify students' initial mathematical problem-solving ability, a preliminary assessment was administered before the intervention. The assessment revealed that many students experienced difficulties across Polya's four stages of problem solving, particularly in devising solution strategies and evaluating the correctness of their solutions. These findings indicate that students' conceptual understanding had not yet developed into flexible problem-solving competence, thereby highlighting the need for instructional approaches that actively engage students in constructing mathematical knowledge through meaningful contexts.

Based on the theoretical rationale, previous empirical findings, and classroom observations, the present study addresses an important gap by investigating the effectiveness of the Realistic Mathematics Education approach in improving ninth-grade students' mathematical problem-solving ability within the context of Indonesian junior secondary education. Unlike many previous studies, this research explicitly operationalizes the five principles of RME during classroom instruction and evaluates students' mathematical problem-solving ability using Polya's four problem-solving indicators. Therefore, this study contributes both theoretically by strengthening the relationship between RME and mathematical problem-solving theory and practically by providing empirical evidence to support mathematics instruction under the implementation of *Kurikulum Merdeka*.

Accordingly, this study aims to examine the effect of the Realistic Mathematics Education (RME) approach on ninth-grade students' mathematical problem-solving ability at SMPN 10 Padang by comparing students who receive RME instruction with those who receive conventional mathematics instruction. Drawing upon the theoretical principles of Realistic Mathematics Education and previous empirical evidence, this study hypothesizes that students taught through the RME approach will demonstrate significantly higher mathematical problem-solving ability than students taught through conventional instruction.

METHODS

Research Design

This study employed a quasi-experimental research design using a nonequivalent posttest-only control group design to investigate the effect of the Realistic Mathematics Education (RME) approach on ninth-grade students' mathematical problem-solving ability. A quasi-experimental design was selected because the researcher was unable to randomly assign individual students to experimental and control groups due to the school's existing classroom organization (Creswell & Creswell, 2022). Instead, intact classes were used while maintaining the regular teaching schedule.

A posttest-only design was adopted to minimize testing effects that might arise if students were exposed to similar mathematical problem-solving tasks before the intervention. Since the research focused on comparing the effectiveness of two instructional approaches, students' mathematical problem-solving ability was measured only after the treatment had been completed. To reduce threats to internal validity associated with the absence of a pretest, both groups studied the same mathematics topic, followed the same curriculum, received the same instructional time allocation, and were taught under comparable classroom conditions. The participating classes were also selected through cluster random sampling from the ninth-grade population, and consultation with the mathematics teacher confirmed that the selected classes had comparable academic characteristics before the intervention.

Descriptive statistics were employed to summarize students' mathematical problem-solving performance, while inferential statistics were used to determine whether the differences between the experimental and control groups were statistically significant. The research design is presented in Table 1.

Table 1. Research Design

Group	Treatment	Postest
Experimental	X	O
Control	-	O

Source: (Hastjarjo, 2019)

Notes:
X : Realistic Mathematics Education (RME) approach
- : Conventional learning approach
O : Final test (Posttest) of mathematical problem-solving ability

Participants

The population of this study consisted of all ninth-grade students at SMPN 10 Padang during the 2025/2026 academic year. Because students had already been organized into intact classrooms by the school, cluster random sampling was employed to select the research sample. Two classes were randomly selected from the population. Class IX.1 was assigned as the experimental group and Class IX.2 served as the control group. Each class consisted of 32 students, resulting in a total sample of 64 students.

Both groups studied the same mathematics topic, namely Exponents and Radicals, under the Independent Curriculum (Kurikulum Merdeka). The duration of the intervention, instructional objectives, learning materials, and assessment schedule were equivalent across both groups. The only difference between the groups was the instructional approach implemented during classroom learning.

Learning Intervention

The experimental group received instruction using the Realistic Mathematics Education (RME) approach, whereas the control group was taught through conventional mathematics instruction consisting primarily of teacher explanations, worked examples, question-and-answer sessions, and individual exercises.

The instructional activities in the experimental class were designed according to the theoretical framework of Freudenthal (1991), Treffers (1987), and Gravemeijer (1994), who describe mathematics as a human activity that should be learned through meaningful situations. Accordingly, five fundamental principles of RME were integrated throughout the learning process:

1. Use of meaningful contexts, in which learning began with authentic contextual problems related to students' daily experiences.
2. Model of to model for, whereby students transformed contextual situations into informal mathematical models before developing formal mathematical representations.
3. Students' contribution, allowing students to construct and explain their own mathematical strategies.
4. Interactivity, encouraging discussion, collaboration, and comparison of multiple solution strategies.
5. Intertwinement, connecting mathematical concepts with previous knowledge and other mathematical topics.

Through these activities, students progressively developed formal mathematical understanding from meaningful contextual experiences while actively constructing their own knowledge. Table 2 summarizes the implementation of the RME principles during classroom instruction.

Table 2. Implementation of RME Principles

RME Principle	Classroom Activities
Meaningful Context	Learning begins with contextual problems related to students' daily life.
Model of → Model for	Students develop informal models before constructing formal mathematical concepts.
Students' Contribution	Students explore, explain, and justify their own solution strategies.
Interactivity	Students discuss, compare, and evaluate different mathematical solutions collaboratively.
Intertwinement	Students connect exponents and radicals with previous mathematical concepts and real-life applications.

The overall learning procedures implemented in both groups are summarized in Table 3.

Table 3. Learning Procedures

Meeting	Eksperimental Group (RME)	Control Group
1	Contextual problem orientation and group discussion	Teacher explanation of concepts and examples
2	Mathematical modeling and collaborative problem solving	Guided practice
3	Presentation and discussion of multiple solution strategies	Individual exercises
4	Solving contextual mathematical problems	Teacher-led practice
5	Reflection and mathematical generalization	Review and reinforcement
6	Posttest	Posttest

Research Instrument

The research instrument consisted of a mathematical problem-solving essay test administered as the posttest. The instrument comprised five contextual essay questions covering the topic of Exponents and Radicals and was completed within 120 minutes. Each question required students to solve non-routine mathematical problems by applying conceptual understanding, mathematical reasoning, and problem-solving strategies.

The instrument was developed based on Polya's (1973) four stages of mathematical problem solving, which consist of understanding the problem, devising an appropriate solution plan, carrying out the planned strategy, and looking back to review and verify the solution obtained. Each test item was aligned with one learning objective and assessed all four indicators of mathematical problem-solving ability. The blueprint of the instrument is presented in Table 4.

Table 4. Blueprint of the Mathematical Problem-Solving Test

Item	Mathematics Topic	Cognitive Level	Polya's Indicators
1	Multiplication of Exponents	C3-C6	Understanding, Planning, Carrying Out, Looking Back
2	Division of Exponents	C3	Understanding, Planning, Carrying Out, Looking Back
3	Negative Exponents	C4	Understanding, Planning, Carrying Out, Looking Back
4	Radicals	C5	Understanding, Planning, Carrying Out, Looking Back
5	Scientific Notation	C4	Understanding, Planning, Carrying Out, Looking Back

Students' responses were scored using an analytic rubric adapted from Polya's problem-solving framework. Scores were assigned separately for each indicator to evaluate students' understanding of the problem, planning ability, execution of mathematical procedures, and verification of solutions. A summary of the scoring rubric is presented in Table 5, while the complete rubric is provided in Appendix A.

Table 5. Summary of the Scoring Rubric

Indicators	Assessment Criteria
Understanding the problem	Identifying relevant information and interpreting the problem correctly
Devising a plan	Selecting appropriate concepts and solution strategies
Carrying out the plan	Applying mathematical procedures accurately and systematically
Looking back	Checking the correctness of the solution and interpreting the result

Prior to data collection, the instrument and learning materials were reviewed by two experts in mathematics education to establish content validity. Revisions were made based on the validators' recommendations to improve the clarity of contextual problems and ensure alignment with Polya's problem-solving indicators. The revised instrument was subsequently piloted with 30 ninth-grade students at SMP Negeri 31 Padang.

Item analysis indicated that all five essay questions demonstrated moderate difficulty levels and acceptable discrimination indices, and therefore all items were retained for the final test. The internal consistency of the instrument was evaluated using Cronbach's alpha, yielding a reliability coefficient of 0.931, indicating excellent reliability. Accordingly, the instrument was considered appropriate for assessing students' mathematical problem-solving ability.

Data Collection Procedure

Data collection was conducted after obtaining permission from the school. Both groups studied the same mathematics topic over the same instructional period. The experimental class received instruction using the Realistic Mathematics Education approach, whereas the control class was taught using conventional mathematics instruction.

At the conclusion of the intervention, students from both groups completed the mathematical problem-solving posttest under identical testing conditions. Students' responses were assessed using the analytic scoring rubric developed according to Polya's four stages of mathematical problem solving.

Data Analysis

Data analysis was conducted using descriptive and inferential statistics. Descriptive statistics, including the mean, standard deviation, minimum score, and maximum score, were used to summarize students' mathematical problem-solving performance.

Before hypothesis testing, the assumptions of normality and homogeneity of variance were examined. The Anderson–Darling normality test indicated that the experimental group ($p = .161$) and the control group ($p = .216$) were normally distributed. Furthermore, Levene's test showed homogeneous variances between the two groups ($p = .756$). Since both assumptions were satisfied, an independent-samples t-test was employed to compare the posttest scores of the experimental and control groups at a significance level of $\alpha = .05$.

To determine the practical significance of the intervention, Cohen's d was calculated using the pooled standard deviation. Based on the posttest means of the experimental group ($M = 80.75$, $SD = 10.74$) and the control group ($M = 71.19$, $SD = 11.36$), the effect size was 0.87, indicating a large educational effect. Therefore, in addition to statistical significance, the RME approach demonstrated substantial practical effectiveness in improving students' mathematical problem-solving ability.

RESULT AND DISCUSSION

Descriptive Statistic

The mathematical problem-solving ability of students was measured using a posttest administered after the learning intervention. Table 6 presents the descriptive statistics for both groups.

Table 6. Descriptive Statistic of Mathematical Problem-Solving Ability

Group	N	Mean	SD	SE
Experimental (RME)	32	80.75	10.74	1.90
Control (Conventional)	32	71.19	11.36	2.00

Students who learned through the Realistic Mathematics Education (RME) approach obtained a higher mean score (M = 80.75, SD = 10.74) than those who received conventional instruction (M = 71.19, SD = 11.36). The mean difference between the two groups was 9.56 points, indicating better mathematical problem-solving performance among students in the experimental group.

Assumption Testing

The Anderson–Darling normality test was conducted for both groups. The results are summarized in Table 7.

Table 7. Andeson-Darling Normality Test

Group	AD Statistic	p-value	Decision
Experimental (RME)	0.531	0.161	Normal
Control (Conventional)	0.482	0.216	Normal

Both groups obtained p-values greater than 0.05, indicating that the posttest scores were normally distributed. Equality of variance was examined using the F-test.

Table 8. Homogeneity of Variance Test

Test	p-value	Decision
F-test	0.756	Homogeneous

The obtained p-value exceeded the significance level of 0.05, indicating that the variances of the experimental and control groups were homogeneous. Therefore, the assumptions for conducting an independent-samples t-test were satisfied.

Hypothesis Testing

An independent-samples t-test was conducted to determine whether there was a significant difference in mathematical problem-solving ability between students taught using the RME approach and those taught through conventional instruction.

Table 9. Independent-Sample t-Test

Statistic	Value
Mean Difference	9.56
T	3.46
Df	62
P	<0.001
95% Lower Confidence Bound	4.95

The independent-samples t-test revealed a statistically significant difference between the two groups, $t(62) = 3.46$, $p < 0.001$. The positive mean difference indicates that students taught using the Realistic Mathematics Education approach achieved significantly higher mathematical problem-solving scores than students who received conventional instruction.

Effect Size

To evaluate the practical significance of the treatment, Cohen's d was calculated using the pooled standard deviation.

Table 10. Effect Size

Statistic	Value
Mean Difference	9.56
Pooled SD	11.05

Cohen's d	0.87

The calculated effect size was Cohen's d = 0.87, indicating a large practical effect according to Cohen's classification. This result suggests that the RME approach produced not only statistically significant improvements but also educationally meaningful gains in students' mathematical problem-solving ability.

Development of Students' Mathematical Problem-Solving Ability During the Intervention

To monitor students' learning progress throughout the intervention, formative quizzes were administered at the end of each instructional meeting in the experimental class. These quizzes served as formative assessments and were not used as the primary evidence for evaluating the effectiveness of the intervention.

Table 11. Mean Quiz Scores Across Six Meetings

Meeting	Mean Score
I	62.19
II	68.75
III	73.44
IV	77.19
V	78.19
VI	84.06

The mean quiz scores showed a consistent upward trend throughout the six instructional meetings. Students' average performance increased from 62.19 in the first meeting to 84.06 in the sixth meeting, indicating continuous improvement in mathematical problem-solving performance during the implementation of the RME approach.

Although minor variations occurred between consecutive meetings, the overall pattern suggests that students gradually developed greater confidence and proficiency in solving contextual mathematical problems as learning progressed.

Development of Problem-Solving Ability Across Polya's Indicators

Students' quiz performance was further analyzed based on the four indicators of mathematical problem-solving adapted from Polya's framework.

Table 12. Mean Scores by Problwm-Solving Indicator

Indicator	I	II	III	IV	V	VI
Understanding the problem	64.58	69.79	77.08	69.79	83.33	85.42
Devising a plan	54.69	37.50	48.44	67.19	76.56	79.69
Carrying out the plan	72.92	85.42	82.29	88.54	78.13	84.38
Looking back	50.00	73.44	79.69	81.25	71.88	85.94

Different patterns of development were observed across the four indicators. The understanding the problem indicator showed a generally increasing trend, reaching its highest score of 85.42 in the final meeting. The devising a plan indicator initially decreased during the second meeting before showing steady improvement throughout the remaining sessions. The carrying out the plan indicator consistently produced the highest scores across most meetings, while the looking back indicator demonstrated the greatest improvement, increasing from 50.00 in the first meeting to 85.94 in the final meeting.

Posttest Performance by Mathematical Problem-Solving Indicator

To examine students' mathematical problem-solving performance in greater detail, posttest scores were analyzed according to four indicators derived from Polya's problem-solving stages.

Table 13. Mean Posttest Scores by Problem-Solving Indicator

Indicator	Experimental	Control
Understanding the problem	86.48	71.46
Devising a mathematical model	70.94	60.00
Carrying out the solution	85.63	78.33
Interpreting the solution	75.63	71.25

Students in the experimental group outperformed those in the control group across all four indicators. The largest difference was observed in the understanding the problem indicator, whereas the smallest difference occurred in the interpreting the solution indicator. These findings indicate that the RME approach contributed to improvements throughout the mathematical problem-solving process rather than only at a single stage.

Performance on Individual Problem-Solving Indicators

Further analysis was conducted to examine students' performance on each posttest item. Across all five problems, the experimental group consistently obtained higher average scores than the control group on the understanding the problem indicator. Similar patterns were found for the devising a plan, carrying out the solution, and interpreting the solution indicators. The most noticeable differences occurred in problems requiring students to formulate mathematical models from contextual situations and justify their solution strategies. In contrast, the performance gap between the two groups was relatively smaller on problems involving interpretation of the final solution, suggesting that both groups experienced similar challenges in evaluating and communicating mathematical conclusions.

Overall, the posttest results consistently demonstrate that students who learned through the Realistic Mathematics Education approach achieved better performance across all stages of mathematical problem-solving than students who experienced conventional mathematics instruction.

Discussion

The findings of this study demonstrate that the Realistic Mathematics Education (RME) approach significantly improved ninth-grade students' mathematical problem-solving ability compared with conventional instruction. Students in the experimental class achieved a significantly higher posttest mean score (80.75) than those in the control class (71.19), with a mean difference of 9.56 points. Statistical analysis confirmed that the difference was significant ($t(62) = 3.46$, $p < 0.001$), while Cohen's d of 0.87 indicated a large practical effect. These findings suggest that the superiority of the RME approach was not only statistically significant but also educationally meaningful, indicating that contextual mathematics learning can substantially enhance students' mathematical problem-solving ability.

The effectiveness of the Realistic Mathematics Education (RME) approach observed in this study is also consistent with broader developments in contemporary mathematics education research, which emphasize that meaningful learning occurs when students actively construct mathematical ideas through exploration, discussion, and reflection rather than merely reproducing procedures. Freudenthal (1991) argued that mathematics should be regarded as a human activity in which learners reinvent mathematical ideas through meaningful experiences. Consistent with this perspective, recent research has highlighted that effective mathematics instruction should engage students in contextual, interactive, and collaborative learning processes that promote conceptual understanding and higher-order thinking.

A comprehensive synthesis by Koskinen and Pitkäniemi (2022) concluded that meaningful mathematics learning is best achieved when instruction integrates authentic contexts, social interaction, teacher guidance, and opportunities for students to communicate their mathematical reasoning. Likewise, recent reviews have emphasized that dialogic and reflective classroom practices strengthen mathematical reasoning, problem-solving, and metacognitive regulation by encouraging students to justify, evaluate, and refine their thinking throughout the learning process. These contemporary perspectives closely align with the fundamental principles of RME, reinforcing its relevance as an instructional approach for developing students' higher-order mathematical thinking and mathematical problem-solving ability.

The improvement observed in this study further indicates that contextual learning functions as an effective bridge between conceptual understanding and mathematical problem solving. Rather than introducing formulas directly, the RME approach enabled students to interpret authentic situations before constructing mathematical representations. This finding supports Muhaimin et al. (2024), who argued that mathematical literacy develops when students learn to formulate, employ, and interpret mathematics in meaningful real-life situations. Likewise, Nguyen (2023) reported that contextual learning embedded within RME significantly improved students' mathematical problem-solving competency because learners progressively transformed realistic situations into formal mathematical reasoning. Collectively, these findings suggest that contextualization is not merely an instructional strategy but a mechanism through which students develop conceptual understanding that can be transferred to unfamiliar mathematical problems.

Second, the principle of guided reinvention encouraged students to construct their own solution strategies instead of merely reproducing teacher demonstrations. Throughout classroom discussions, students explored multiple approaches before formal mathematical procedures were introduced. This process strengthened conceptual understanding because mathematical ideas emerged naturally from students' reasoning rather than from memorization. Consequently, students demonstrated better performance in implementing solution strategies than those taught conventionally. This finding is consistent with Gravemeijer's (1994) proposition that students develop stronger conceptual understanding when mathematical knowledge is progressively reinvented through guided exploration.

The third mechanism relates to mathematization, whereby students gradually transformed contextual situations into mathematical models (horizontal mathematization) before refining these models into formal mathematical procedures (vertical mathematization). Such transitions between realistic situations and symbolic representations enabled students to understand not only how mathematical procedures work but also why they should be applied in particular situations. This finding is supported by Nguyen (2023), who reported that students' problem-solving competency improved significantly when instruction emphasized progressive mathematization through contextual learning rather than direct procedural teaching. These results reinforce the view that mathematical problem solving requires flexible movement between contextual understanding and formal mathematical reasoning rather than isolated procedural competence.

Interactivity also contributed substantially to students' learning. During RME lessons, students discussed alternative strategies, justified their reasoning, and evaluated classmates' solutions through collaborative classroom activities. These interactions exposed students to diverse methods of solving the same problem and encouraged mathematical argumentation. Such collaborative reasoning is consistent with social constructivist perspectives, which argue that mathematical understanding develops through communication and negotiation of meaning. Consequently, students became more confident in selecting and defending appropriate solution strategies when solving unfamiliar problems. Similar findings were reported by Ventista et al. (2025), who found that collaborative problem solving was one of the primary mechanisms through which RME improved students' mathematical performance compared with conventional instruction.

Reflection represented another important component contributing to students' improvement. At the conclusion of each lesson, students reviewed their solutions, examined computational errors, and compared alternative approaches. This reflective activity appears to explain the considerable improvement observed in the indicator of checking solutions, although this indicator remained the lowest among the four assessed dimensions. Students often regarded obtaining the correct numerical answer as the final stage of problem solving, whereas systematic verification requires higher levels of metacognitive awareness. The RME approach provided opportunities for reflection, but developing reflective thinking requires sustained practice beyond the duration of the present study.

Beyond improving procedural accuracy, reflective activities promote students' metacognitive regulation by encouraging them to monitor, evaluate, and revise their mathematical reasoning. Wibawa et al. (2025) similarly emphasized that metacognitive reflection strengthens students' ability to identify misconceptions, justify mathematical arguments, and improve subsequent problem-solving performance. These findings suggest that reflection should be considered an integral component of mathematics instruction rather than merely a concluding classroom activity. Consequently, integrating structured reflection into RME not only helps students verify the correctness of their solutions but also develops the self-regulatory thinking skills required for solving increasingly complex mathematical problems.

The progression of students' quiz performance across the six instructional meetings further illustrates how students gradually adapted to the RME learning process. Average quiz scores increased from 62.19 during the first meeting to 84.06 at the sixth meeting. Improvements were also observed across all four Polya indicators, although the rate of improvement varied. The planning indicator exhibited the greatest fluctuation because developing solution strategies requires students to integrate conceptual understanding, prior mathematical knowledge, and strategic reasoning simultaneously. During the initial meetings, many students still depended heavily on teacher guidance when selecting solution methods. However, as classroom discussions became increasingly interactive and students gained experience solving contextual problems, their strategic planning ability gradually improved. Nevertheless, these quiz results should be interpreted cautiously because they describe learning progression within the experimental class rather than provide causal evidence of treatment effectiveness.

The findings of this study are consistent with a growing body of international evidence demonstrating the effectiveness of the Realistic Mathematics Education (RME) approach in improving students' mathematical problem-solving ability. Ventistas et al. (2025) reported that secondary school students receiving RME instruction significantly outperformed those in conventional classrooms on mathematical problem-solving tasks requiring reasoning and collaborative thinking. Similarly, Nguyen (2023) found that contextual mathematics instruction based on RME improved students' problem-solving competency by facilitating progressive mathematization from realistic situations to formal mathematical reasoning. Furthermore, Ningrum et al. (2025), through a bibliometric analysis, demonstrated that RME has become one of the most rapidly expanding research areas in mathematics education because of its consistent contribution to conceptual understanding, mathematical reasoning, and higher-order thinking skills. These international findings indicate that the effectiveness of RME has been consistently observed across different educational systems and mathematical topics, thereby strengthening the external validity of the present study.

The present findings are likewise consistent with previous studies conducted in Indonesia. Marita et al. (2025), Alfarisy et al. (2025), Arrahim et al. (2025), Ayumni et al. (2025), and Pramitasuri et al. (2025) similarly reported that students taught using the RME approach significantly outperformed those receiving conventional instruction in mathematical problem-solving tasks. Furthermore, Lestari et al. (2026), through a systematic literature review, concluded that RME consistently enhances students' conceptual understanding, mathematical reasoning, and problem-solving performance across various mathematical topics and educational levels. Compared with these previous studies, the present research contributes additional evidence by examining students' learning progression across six consecutive learning sessions while analyzing mathematical problem-solving performance based on Polya's four indicators. This provides a more comprehensive understanding of how students gradually develop mathematical problem-solving ability during the implementation of the RME approach.

Nevertheless, unlike most previous Indonesian studies that primarily compared posttest achievement, the present study additionally examined students' learning progression across six instructional meetings using Polya's four problem-solving indicators. This analysis provides richer evidence regarding how students gradually developed mathematical problem-solving ability during the implementation of RME rather than simply demonstrating differences in final achievement. By combining posttest comparisons with continuous classroom assessment, this study offers a more comprehensive understanding of the learning processes underlying the effectiveness of RME in junior secondary mathematics classrooms.

Beyond confirming previous findings, this study contributes to the implementation of Indonesia's Merdeka Curriculum. The curriculum emphasizes contextual learning, higher-order thinking skills, student-centered instruction, and authentic problem solving, all of which closely align with the principles of RME. Therefore, the present findings provide empirical support for integrating RME into junior secondary mathematics classrooms as an effective pedagogical approach for fostering meaningful learning experiences and strengthening students' mathematical problem-solving ability.

Despite these encouraging findings, several limitations should be acknowledged. First, the study employed a nonequivalent posttest-only control group design, preventing verification of the initial equivalence between the experimental and control groups through pretest data. Second, the intervention involved only two classes from a single junior secondary school and focused exclusively on exponents and radicals, limiting the generalizability of the findings. Finally, this study examined only cognitive learning outcomes. Future research is therefore recommended to employ more rigorous experimental designs involving multiple schools, investigate different mathematical topics, and examine the effects of RME on broader outcomes such as mathematical literacy, reasoning, creativity, self-efficacy, motivation, and metacognitive regulation.

Overall, the present study demonstrates that the Realistic Mathematics Education approach provides meaningful learning experiences through contextual exploration, guided reinvention, progressive mathematization, collaborative interaction, and reflective thinking. These learning characteristics explain why students receiving RME achieved significantly better mathematical problem-solving performance than those taught using conventional instruction. Accordingly, the findings strengthen the growing body of national and international evidence supporting RME as an effective instructional approach for developing students' higher-order mathematical thinking and problem-solving competence.

CONCLUSION

This study examined the effect of the Realistic Mathematics Education (RME) approach on ninth-grade students' mathematical problem-solving ability at SMPN 10 Padang. The findings indicate that students who learned through the RME approach achieved significantly higher mathematical problem-solving scores than those who received conventional instruction ($t(62) = 3.46$, $p < 0.001$), with a large practical effect (Cohen's $d = 0.87$). These findings suggest that learning activities incorporating contextual problems, guided reinvention, mathematization, interaction, and reflection can effectively support students' mathematical problem-solving ability. Despite these positive findings, this study has several limitations. The use of a nonequivalent posttest-only control group design prevented the verification of initial group equivalence, and the study involved only two classes from one junior secondary school, limiting the generalizability of the findings. Therefore, future studies are recommended to employ pretest-posttest or randomized experimental designs with larger and more diverse samples. Further research should also investigate the effectiveness of RME across different mathematical topics and its impact on other learning outcomes, such as mathematical reasoning, mathematical literacy, and students' learning motivation.

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