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The Effectiveness of Realistic Mathematics Education (RME) in Improving the Mathematical Problem Solving Ability of Junior High School Students in One Variable Linear Equation Material

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Abstract:
Mathematical problem solving ability is one of the essential competencies that need to be developed in mathematics education. However, this ability remains relatively low among some students, indicating the need for a more meaningful instructional approach, one of which is the Realistic Mathematics Education (RME)approach. This study aims to analyze the effectiveness of the RME approach in improving junior high school students' mathematical problem solving ability on the topic of Linear Equations in One Variable. The study used a quasi experimental method using a pretest-posttest control group design. The participants consisted of 60 seventh-grade students at SMPN 5 Medan, who were divided into an experimental group and a control group, with 30 students in each group. The experimental group received instruction based on the RME approach over eight learning sessions, whereas the control group received conventional instruction through an expository approach. Data were collected using a mathematical problem-solving test that assessed the indicators of understanding the problem, devising a solution plan, implementing the plan, and reviewing the obtained solution. The results showed that the mean posttest score of the experimental group was higher than that of the control group. The N-gain analysis also indicated a greater improvement in mathematical problem-solving ability among students in the experimental group compared with those in the control group. The results of the statistical analysis revealed a significant difference between the mathematical problem-solving abilities of students who learned through the RME approach and those who received conventional instruction. These findings confirm that the RME approach is effective for teaching Linear Equations in One Variable because it utilizes real-world contexts that are relevant to students' everyday lives. Therefore, the RME approach can serve as an alternative strategy for mathematics instruction at the junior high school level to enhance students' mathematical problem solving ability.

Abstrak:
Kemampuan pemecahan masalah matematis merupakan salah satu kompetensi penting yang perlu dikembangkan dalam pembelajaran matematika. Namun,

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kemampuan tersebut masih relatif rendah pada sebagian siswa sehingga diperlukan pendekatan pembelajaran yang lebih bermakna, salah satunya melalui pendekatan ii (RME). Penelitian ini bertujuan untuk menganalisis efektivitas pendekatan Realistic Mathematics Education dalam meningkatkan kemampuan pemecahan masalah matematis siswa SMP pada materi Persamaan Linear Satu Variabel (PLSV). Penelitian menggunakan metode eksperimen semu (quasi experiment) dengan desain pretest-posttest control group. Subjek penelitian terdiri atas 60 siswa kelas VII SMP Negeri 5 Medan yang dibagi menjadi kelompok eksperimen dan kelompok kontrol, masing-masing 30 siswa. Kelompok eksperimen memperoleh pembelajaran berbasis RME selama delapan pertemuan, sedangkan kelompok kontrol memperoleh pembelajaran konvensional dengan pendekatan ekspositori. Pengumpulan data menggunakan instrumen tes kemampuan pemecahan masalah yang meliputi indikator memahami masalah, merencanakan penyelesaian, melaksanakan rencana, dan memeriksa kembali hasil. Hasil penelitian menunjukkan bahwa rata-rata posttest kelompok eksperimen lebih tinggi dibandingkan kelompok kontrol. Perhitungan N-gain juga menunjukkan peningkatan kemampuan pemecahan masalah matematis yang lebih baik pada kelompok eksperimen dibandingkan kelompok kontrol. Hasil pengujian statistik mengindikasikan adanya perbedaan yang signifikan antara kemampuan pemecahan masalah matematis peserta didik yang belajar menggunakan pendekatan RME dan siswa yang memperoleh pembelajaran konvensional. Temuan ini menegaskan bahwa pendekatan RME efektif diterapkan pada materi PLSV karena memanfaatkan konteks nyata yang relevan dengan kehidupan siswa. Dengan demikian, pendekatan RME dapat dijadikan sebagai alternatif strategi pembelajaran matematika di SMP untuk meningkatkan kemampuan pemecahan masalah matematis peserta didik.

Keywords:
Realistic Mathematics Education, Mathematical Problem Solving,
Single Variable Linear Equations, Junior High School Students

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INTRODUCTION

Mathematics education plays an important role in shaping logical, analytical, and systematic thinking skills in students. One of the fundamental skills that students must master in learning mathematics is problem solving skills. This ability is not only needed in an academic context, but also in everyday life, which is increasingly complex and competitive (National Council of Teachers of Mathematics, 2020).

Havill (2020) Polya defines problem-solving as an effort to find a way out of a difficulty to achieve a goal that cannot be obtained directly. According to Polya, the problem-solving process involves four stages, namely: (1) understanding the problem, (2) planning the solution, (3) implementing the plan, and (4) re-examining the results. Mathematical problem-solving skills are an important benchmark of mathematics learning success because they reflect higher-order thinking skills (HOTS).

Empirically, students' mathematical problem-solving skills in Indonesia are still relatively low. The results of the Programme for International Student Assessment (PISA) in 2022 show that Indonesia is ranked 70th out of 78 participating countries with an average math score of 366, far below the international average of 472. This finding is strengthened by the results of the National Assessment (AKM), which shows that the numeracy literacy achievement of Indonesian students at the junior high school level is still dominated by sufficient and insufficient levels, especially in algebra content (Ministry of Education and Culture, 2022). This condition illustrates that mathematics learning in Indonesia is not optimal in developing students' problem-solving skills, especially in basic algebraic materials such as One-Variable Linear Equations (PLSV).

At the junior high school level, similar problems were also found by several researchers. Research results (Hidayat & Sariningsih, 2018) show that the mathematical problem solving ability of junior high school students is still in the low category, with an average percentage of 41.7%. Meanwhile, Jupri and Drijvers (2016) found that students have difficulties, especially at the stage of planning the solution and re-examining the answers, especially when converting algebraic verbal problems into mathematical models. This condition demands a more effective innovation of mathematics learning approaches, especially in PLSV materials, which are the basis for algebraic understanding at the next level.

One of the learning approaches that is believed to improve students' mathematical problem-solving skills is Realistic Mathematics Education (RME). RME is a mathematics learning approach developed by Freudenthal in the Netherlands, using contextual problems as a starting point for learning (Freudenthal, 1991). The main principle of RME is that mathematics should be seen as a human activity, not just a collection of facts and rules that must be memorized.

Previous research has proven the effectiveness of RME in improving students' various mathematical abilities. Research by Fauzan, Slettenhaar, and Plomp (2002) shows that the implementation of RME in primary schools significantly improves students' understanding of concepts and problem-solving skills. Furthermore, Zulkardi (2002) found that students who studied with RME showed improved mathematical communication skills better than traditional learning. More recent research, such as Noordyana (2018), also shows that RME based learning on algebra materials can improve students' critical thinking skills based on Facione's stages. In addition to RME, other innovative approaches, such as generative learning models, have also been shown to have an effect on the quality of mathematics learning of junior high school students, as found by Maryanti and Suwardi (2024), students of Muhammadiyah Junior High School 05 Medan.

Although research on RME at the junior high school level in Indonesia has been largely conducted, most of the research has focused on geometry, fractions, or spatial construction, while the research specifically examines the effectiveness of RME on the material of Single Variable Linear Equations (PLSV) a basic algebraic material that is a prerequisite for many advanced mathematics topics and has proven to be a major source of difficulties for grade VII students (Jupri & Drijvers, 2016), still relatively limited. In addition, the characteristics of grade VII students at SMP Negeri 5 Medan, which is in the socio-cultural context of North Sumatra, have not been widely studied in previous RME research. This gap is the focus of this research, which is to examine the effectiveness of RME specifically in PLSV material for grade VII students.

Research Gravemeijer and Doorman (1999) shows that RME is effective because it allows students to rediscover mathematical concepts through horizontal and vertical mathematization processes. This process helps students understand mathematics in depth so that they are able to apply this knowledge in solving various problems. In addition, Van Den Heuvel-Panhuizen (2003) affirms that RME encourages students to actively build their own knowledge based on real experience. If problem solving skills are not optimally developed at the junior high school level, students will face ongoing difficulties at the next level of education and will face challenges in competing in the 21st-century world of work that demands critical thinking skills and contextual problem-solving (National Council of Teachers of Mathematics, 2020).

Based on this description, the objectives of this study are: (1) to analyze the effectiveness of RME in improving the mathematical problem-solving ability of junior high school students in PLSV materials; (2) to compare the improvement in mathematical problem-solving skills between students who study with RME and conventional learning; and (3) to describe students' responses to RME-based learning. The results of this study are expected to contribute to the development of more effective mathematics learning practices in junior high schools, especially in basic algebra materials.

METHODS

This study uses a quasi-experiment method with a pretest posttest control group design. The quantitative approach was chosen because the researcher intended to measure the difference in the effectiveness of the two learning treatments measurably and objectively.

The subjects of the study were 60 grade VII students of SMP Negeri 5 Medan who were selected using the cluster random sampling technique. The group selection was carried out by drawing two of the six classes VII available at the school, first ensuring that both classes had a relatively equal average mid-semester exam score and homogeneous variance (based on the results of the initial homogeneity test). The selected classes were then redrawn to determine the experimental group and the control group. Students were divided into two groups, namely the experimental group (30 students) who learned with the RME approach, and the control group (30 students) who received conventional learning. The selection of subjects took into account the equivalence of the initial abilities of the two groups based on the previous mid-semester exam scores. The inclusion criteria for participants in this study are: (1) registered as active students in grade VII at SMP Negeri 5 Medan in the 2023/2024 school year; (2) present at all intervention learning sessions and take part in the pretest and posttest; and (3) willing to fill out a complete student response questionnaire. Exclusion criteria include: (1) students who do not attend more than two learning meetings (more than 25% of the total eight meetings); and (2) students who did not take the pretest or posttest. Of the total 60 students enrolled, all met the inclusion criteria, and no students needed to be excluded from the analysis, so the data analyzed was complete data from 30 students per group. In the case of absences, no students were found to be absent from more than one meeting, and incomplete data were not found during the data collection process.

The research instrument used consists of two parts. First, the mathematical problem solving ability test in the form of 5 contextual problem-based description questions developed based on four Polya problem-solving indicators, namely: (1) understanding problems; the ability to identify known and asked information; (2) planning settlements; the ability to determine appropriate settlement strategies and steps; (3) implementing the plan; the ability to implement the completion plan correctly; and (4) double checking; the ability to verify the correctness of results and the completion process. The test instrument has been validated by three expert lecturers in mathematics education with a minimum qualification of S3 and junior high school mathematics teaching experience, who assessed aspects of indicator suitability, question construction, and language suitability using a validation sheet on a scale of 1-4. The validation results showed an average score of 3.6 (very valid category) with a validity coefficient of Aiken's V content of 0.87. Furthermore, the reliability of the instrument was calculated using Cronbach's Alpha coefficient, and a value of 0.87 was obtained, which was categorized as high based on the criteria of Guilford (1956), namely the coefficient of 0.70-0.90 included in the category of high reliability. Second, a student response questionnaire consisting of 20 statements using a Likert scale of 1-4 to find out students' responses to RME-based learning.

The implementation of learning lasted for 8 meetings on the material of One Variable Linear Equation (PLSV) with the aim of learning so that students were able to: (1) model daily situations into the form of one-variable linear equations, (2) solve PLSV using equivalence properties, and (3) apply PLSV to solve contextual problems. The experimental group obtained RME learning that followed the five characteristics of RME according to Treffers (1987), namely: (1) the use of real context, (2) the use of models, (3) the use of student construction, (4) interactivity, and (5) interconnectedness. As a concrete example of the application of a real context, students are given problems of buying and selling transactions in the school canteen, calculating the age difference of family members, and the distribution of pocket money, which is then modeled into the form of PLSV, such as $ax + b = c$. Meanwhile, the control group obtained conventional learning with an expository approach, where the teacher explained the concepts and procedures for solving PLSV directly, followed by structured problem exercises.

Data analysis uses several statistical techniques. First, the normality test uses the Kolmogorov Smirnov test, and the homogeneity test uses the Levene

test as a prerequisite test. Second, an independent t-test to compare the average posttest scores of the two groups, with the rationale that this test is used to determine whether the mean difference between the two independent groups is statistically significant. Third, normalized N-gain calculations (Hake, 1999) were used to measure the magnitude of the increase in problem-solving ability in each group while controlling the effect of differences in initial pretest scores, with the following criteria: N-gain ≥ 0.70 (high), 0.30 ≤ N-gain < 0.70 (Medium), and N-gain < 0.30 (low). Fourth, descriptive analysis to describe students' responses to RME learning. All statistical analyses were conducted using SPSS software version 25 with a significance level of 0.05.

RESULTS AND DISCUSSION

Based on the results of the mathematical problem-solving ability test given to 60 students, a descriptive statistical picture of the two groups was obtained as explained in table 1 below.

Table 1. Descriptive Statistics of Mathematical Problem Solving Ability Test

Statistics	Pretest Experiment	Posttest Experiment	Control Pretest	Posttest Control
N	30	30	30	30
Average	45.67	78.43	44.90	65.20
Std. Deviation	8.34	7.62	8.11	8.95
Minimum Score	30	62	28	48
Maximum Value	62	95	60	88

From table 1 above, it can be seen that the average pretest of the experimental group (45.67) and the control group (44.90) did not differ much, which indicates that the initial ability of the two groups was relatively equal. After treatment, the average posttest of the experimental group (78.43) was much higher than that of the control group (65.20). This provides an early indication that RME learning is more effective in improving students' mathematical problem solving skills.

Table 2. Results of N-Gain Analysis of Both Groups

Groups	Average Pretest	Posttest Average	N-Gain (Category)
Experiments	45.67	78.43	0.64 (Medium)
Controls	44.90	65.20	0.38 (Medium)

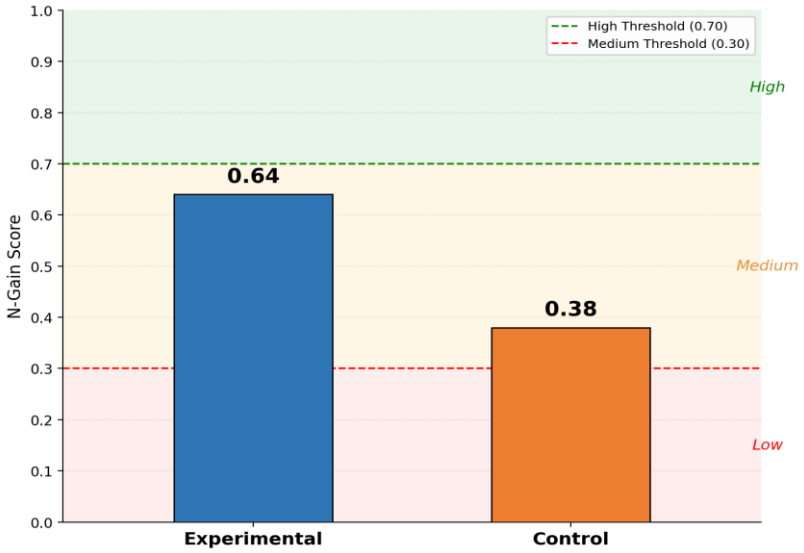


Figure 1. Comparison Bar Graph of N-Gain Values of Experimental and Control Groups

Figure 1 visualizes the comparison of N-gain values between the experimental group (0.64) and the control group (0.38). The N-gain value of the experimental group was higher than that of the control group, although both were in the medium category according to the criteria of Hake (1999). This difference of 0.26 points shows that RME-based learning provides a much more substantial increase in problem-solving skills than conventional learning.

The N-gain category in table 2 follows the criteria of Hake (1999), namely N-gain ≥ 0.70, including the high category, 0.30 ≤ N-gain < 0.70, including the medium category, and N-gain < 0.30, including the low category. Based on these criteria, the experimental group obtained an N-gain of 0.64, which was in the medium category with a value close to the high category limit, while the control group obtained an N-gain of 0.38, which was also in the medium category but with a value close to the lower limit of the category. Although both groups were in the same category, the difference in N-gain (0.64 versus 0.38) showed that the improvement in mathematical problem solving skills in the experimental group was much greater than in the control group, so that RME learning had a more substantial impact on improving students' mathematical problem-solving skills compared to conventional learning.

The results of the prerequisite test showed that the data were normally distributed (Kolmogorov Smirnov test: $p = 0.087 > 0.05$ for the experimental group; $p = 0.093 > 0.05$ for the control group) and homogeneous (Levene test: p

= 0.312 > 0.05). With the fulfillment of these two prerequisite tests, independent t-tests can be performed. The results of the t-test showed t-count (5.87) > t-table (2.00) with a significance value of $p < 0.001$. This suggests that there is a significant difference in mathematical problem-solving skills between students who study with RME and students who study conventionally. The outputs of the normality, homogeneity, and independent t-test of SPSS version 25 are presented in full in the study appendix.

Table 3. N-Gain Analysis Results Based on Polya Troubleshooting Indicators

Troubleshooting Indicators	N-Gain Experiment	Categories	N-Gain Control	Categories
Understanding the problem	0.68	Medium	0.41	Medium
Plan the completion	0.71	Height	0.35	Medium
Execute the plan	0.59	Medium	0.37	Medium
Check back	0.58	Medium	0.34	Medium

Further analysis of each problem-solving indicator showed that the greatest improvement in the experimental group occurred in the indicators of planning completion (N-gain = 0.71, high category) and understanding the problem (N-gain = 0.68, medium category). Meanwhile, improvements in the indicators of implementing plans (N-gain = 0.59) and rechecking (N-gain = 0.58) also belong to the medium category. To ensure that the difference in improvement between the indicators was statistically significant, additional independent t-tests were performed on the gain scores on each indicator between the experimental and control groups. The test results showed that the difference in gain in the indicators of understanding the problem ($t = 4.12$; $p < 0.001$) and planning the solution ($t = 4.85$; $p < 0.001$) was statistically significant, while the difference in the indicators of executing the plan ($t = 2.34$; $p = 0.023$) and rechecking ($t = 2.18$; $p = 0.033$) was also significant albeit with a smaller difference. These findings show that RME has the greatest impact in the early stages of the problem solving process, namely understanding and planning solutions, because learning starts from a real context that is easy for students to understand, helping students identify important information and develop a more systematic solution strategy.

The results of the analysis of the student response questionnaire to RME learning are presented in the following table 4, which illustrates the percentage of positive student responses in each aspect measured.

Table 4. Results of Analysis of Student Responses to RME Learning

Measured Aspects	Average Score (Scale 1-4)	Positive Response Percentage
Increased motivation to learn mathematics	3.32	83.3%
Real context helps to understand the concept of PLSV	3.47	86.7%
Group discussions help find resolution strategies	3.25	81.7%
Average overall response	**3.35**	**83.9%**

Table 4 shows that, in general, 83.9% of students responded positively to RME learning. A total of 83.3% of students stated that RME learning made them more motivated in learning mathematics, and 86.7% of students felt that the use of real context in learning helped them understand PLSV concepts better. These findings are in line with the research of Wahyudi and Winanto (2018), who found that RME significantly increases students' motivation and interest in learning mathematics. Students' motivation to learn can also be increased through the use of technology-based learning media, as shown by Ammy & Maryanti (2023), who developed Android-based mathematics learning media at the University of Muhammadiyah North Sumatra.

The findings of this study are in line with the research of Nuraeni and Luritawaty (2016), which found that the RME approach can significantly improve the mathematical problem solving ability of junior high school students. The advantage of RME in improving problem solving skills is due to several factors that can be explained concretely through the PLSV material studied in this study.

First, the use of the context of real problems in RME helps students understand the meaning of the mathematical problems studied. For example, when students are faced with the problem "Ani bought 3 notebooks and a pencil for Rp2,000, if the price of a notebook is x, then determine the price of a notebook if the total money paid by Ani is Rp17,000", students find it easier to understand the relationship between variables because the context is familiar in daily life. This is in line with the findings (Gravemeijer & Doorman, 1999) that students who are faced with real life situations that they are familiar with are better able to identify relevant information and devise appropriate resolution strategies.

Second, the horizontal and vertical mathematization process in RME encourages students to actively build their knowledge. At the horizontal mathematical level, students turn contextual problems such as the example above into informal mathematical models, for example, by drawing a sketch or writing down the relationship "3 times the price of a book plus 2,000 equals 17,000". Furthermore, through vertical mathematicalization, students develop the informal model into a formal form of PLSV, which is 3x + 2,000 = 17,000, then solve it using the equivalence property to obtain x = 5,000. It is this process of moving from contextual representation to symbolic representation that trains students' high level thinking skills in problem solving (Treffers, 1987) and is directly related to the stage of planning solutions and implementing plans within the framework of Polya (1973).

Third, the characteristics of interactivity in RME provide opportunities for students to discuss, share strategies, and argue. This social interaction enriches students' perspectives in seeing a problem and finding alternative ways to solve it. The research of Sembiring, Hadi, and Dolk (2008) confirms that the interactivity aspect in RME plays an important role in improving students' flexible thinking ability in problem solving, which, in this study, appears to be a significant increase in the indicators of understanding problems and planning solutions, as shown in table 3.

Based on the description above, this study contributes in the form of empirical evidence on the effectiveness of RME in learning to solve algebraic problems, especially in PLSV materials, in the context of junior high school students in North Sumatra, a context that is still underrepresented in previous RME literature that generally focuses on geometry, fractions, or elementary school materials.

Although the results of this study consistently show the advantages of RME, it should be acknowledged that not all previous studies reported uniform results. Some studies have shown that the effectiveness of RME can vary depending on the teacher's readiness to facilitate class discussions and the availability of sufficient learning time for the optimal horizontal-vertical mathematicization process. In this study, the relatively short learning duration (8 meetings) and the limitation on one topic (PLSV) are boundary conditions that need to be considered in interpreting the magnitude of the RME effect found.

This study has several limitations that need to be considered in interpreting the findings. First, the research sample was only taken from one

school, so the generalization of the results needed to be done carefully. Second, the learning intervention lasted only eight meetings, so it was not possible to describe the long term impact of RME. Third, this study only focuses on one mathematical topic, namely, One Variable Linear Equations, so the effectiveness of RME on other topics cannot be ascertained. Fourth, this study has not controlled for the possibility of a teacher effect, i.e., whether the experimental and control groups are taught by the same or different teachers, which can affect the results of the study.

Based on these limitations, further research is recommended to test the effectiveness of RME on different mathematics topics and higher education levels with a larger sample and involving more than one school. In addition, advanced research can use a longitudinal design to observe the long-term impact of RME, as well as use a mixed-methods approach that combines quantitative data with qualitative data, such as interviews and student worksheet analysis, to gain a deeper understanding of students' thinking processes during RME-based learning.

CONCLUSION

Based on the results and discussion, it can be concluded that Realistic Mathematics Education (RME) is effective in improving students' mathematical problem solving skills, which is shown by the average posttest of the experimental group (78.43), which is significantly higher than that of the control group (65.20), with a t-count value (5.87) > t-table (2.00) at a significance level of 0.05 and $p < 0.001$. The improvement in the experimental group's problem solving ability (N-gain = 0.64, medium category near high) was greater than that of the control group (N-gain = 0.38, medium category near low). The biggest improvement occurred in the indicators of planning the solution and understanding the problem, which showed that the use of real context in RME was very helpful for students in the early stages of the problem-solving process, particularly in transforming PLSV contextual problems into formal mathematical models. A total of 83.9% of students responded positively to RME learning, indicating that this approach is not only academically effective but also well-received by students. The implication of this study is the need for junior high school mathematics teachers to apply the RME approach as an innovative alternative in learning mathematical problem solving, especially in basic algebraic materials such as PLSV.

Furthermore, the results of this research can also be considered by curriculum developers and education policymakers in designing teaching materials and teacher training that integrate contextual approaches based on RME.

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Author Contribution	:	IM: Conceptualization, Methodology, Data collection, Data analysis, Writing–Original Draft, Writing–Review & Editing. ID: Conceptualization, Methodology, Validation, Supervision, Instrument Development. KMAF: Conceptualization, Methodology, Validation, Supervision, Instrument Development.
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