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The application of realistic mathematics education approach: Enhancing students' understanding of mathematical concepts through algebra board media

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Abstract.
This study investigates the impact of the Realistic Mathematics Education (RME) approach, utilizing algebra board media, on students' comprehension of mathematical concepts. The research design employed a Nonequivalent control group. The research subjects consisted of 40 students from State Junior High School 8 South Halmahera, Indonesia. The findings demonstrated that the implementation of RME with algebra board media significantly enhanced students' ability to grasp mathematical concepts. The t-test yielded a Sig. (2-tailed) value of 0.000 ($p < 0.05$), rejecting H0 and accepting Ha, indicating a substantial effect. The Effect Size value of 2.52 signifies a "large" effect. The N-gain analysis of the average score of 0.72 (71.84%) indicates that this approach is "quite effective" in augmenting students' understanding of mathematical concepts, aligning with the RME principle of connecting mathematics to reality and facilitating the concrete representation of abstract concepts.

Keywords:
RME; algebra board media; understanding mathematical concepts

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INTRODUCTION

Education plays a pivotal role in the life of a nation, particularly in preparing and producing a high-quality and competitive human resource (Kaur & Bhatia, 2024). The phrase "to advance the intellectual life of the nation", enshrined in the fourth paragraph of the 1945 Indonesian Constitution, represents a primary national goal. This phrase encapsulates the Indonesian nation's aspiration to educate its citizens and equalize educational access across the archipelago to achieve an intellectually advanced society. Within the educational sphere, mathematics education is one form of learning that significantly supports the achievement of these educational objectives (Yudha, 2019).

Mathematical conceptual understanding is a skill that enables individuals to explore and comprehend various mathematical concepts (Ningsih, 2016). According to Fajar et al. (2019), understanding mathematical concepts is a fundamental cornerstone of mathematics learning. Mastery of concepts provides students with the necessary foundation to achieve basic competencies and facilitates their ability to solve mathematical problems. However, many students often encounter difficulties in mastering these concepts due to a range of internal and external factors (Hamda et al., 2025). Consequently, the development of effective educational and instructional methods is essential to support student growth and development in mathematics (Safari & Nurhida, 2024).

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Despite its recognized importance, the quality of mathematics education in Indonesia remains low. According to the 2022 Programme for International Student Assessment (PISA) results, Indonesia ranked 68th out of 81 countries in mathematics, with a score of 366 (OECD, 2023). This condition indicates that a majority of Indonesian students have not yet met expected international standards for mathematical competency. This low achievement suggests fundamental issues within the learning process, including a lack of conceptual mastery, problem-solving skills, and the ability to connect material to real-life contexts (Agustina, 2016).

In practice, a significant number of junior high school students continue to struggle with comprehending concepts, particularly in representing concepts, classifying them, and applying them (Mayasari & Habeahan, 2021). For instance, in the topic of Linear Equations in One Variable (LEOV), many students merely memorize procedural steps without understanding the meaning behind each step. When presented with a word problem such as, "Ani has three times the number of marbles Budi has, plus five more. If their total number of marbles is 20, how many marbles does Ani have?", students are often confused about how to model it mathematically as $3x + 5 = 20$. Even after a teacher's explanation, some students still struggle to articulate why the step of subtracting 5 is performed first or how the final solution of $x=5$ is derived (Nurcahyono et al., 2024).

This difficulty demonstrates that students have not achieved genuine conceptual mastery but are instead following solution examples mechanically (Lolonlun et al., 2022). The low level of conceptual understanding can be attributed to several factors, including instruction that overemphasizes procedures without providing a deep explanation of conceptual meaning (Harahap, 2025), the minimal use of media to visualize relationships between mathematical ideas (Rahmatyas, 2024), a lack of connection to real-world contexts, and limited opportunities for students to discuss and discover concepts themselves through meaningful learning experiences (Manurung, 2024). This subsequently presents a critical challenge for mathematics teachers to address.

Efforts to address this issue can be made by implementing instructional models that engage student interest while helping them construct a profound understanding (Murti & Irwan, 2023). One approach with significant potential for developing mathematical conceptual understanding is Realistic Mathematics Education (RME). This approach uses real-world contexts familiar to students as a starting point for learning, making mathematical concepts easier to grasp and more relevant to daily life (Yulianty, 2019). Furthermore, RME emphasizes the process of knowledge construction by students themselves through mathematization—the act of transforming contextual problems into mathematical models and vice versa—thereby making learning more meaningful and sustainable (Laurens et al., 2017).

Nevertheless, the use of an instructional model alone does not guarantee the optimal achievement of learning objectives. To further support this goal, it is beneficial to integrate instructional media into mathematics learning (Rahmawati, 2022). The use of instructional media in implementing RME is crucial, as media serves as an intermediary that can clarify and visualize abstract concepts, making them more concrete and comprehensible for students (Haerlina et al., 2019). Instructional media also captures student attention and motivates them to participate actively in the learning process, while simultaneously creating an interactive and engaging classroom atmosphere (Farida & Purnomo, 2025). Additionally, media can effectively bridge real-world contexts with mathematical representations—for example, through images, videos, simulations, or manipulatives—thus optimizing the mathematization process within RME (Hairunnisa, 2023). Therefore, the integration of instructional media not only supports conceptual understanding but also strengthens student engagement and enhances the overall quality of instruction.

One mathematical topic that continues to pose difficulties for students is Linear Equations in One Variable (LEOV). Recent research indicates that these challenges persist across several aspects. Rayhan et al. (2025) found that students often struggle to recognize mathematical models

from word problems, perform basic operations such as addition, subtraction, and multiplication, and comprehend the information presented. A similar finding was reported by Qetrani et al. (2021), who noted that many students lack an understanding of the concept of equivalence in both linear equations and inequalities in one variable, leading to errors in interpreting or simplifying equations. These findings underscore the need for instructional strategies that are not only conceptual but also contextual, such as the application of Realistic Mathematics Education (RME) combined with instructional media to help visualize contexts, clarify the process of mathematization, and increase student engagement in meaningfully understanding LEOV (Ardani et al., 2023).

Although various studies have demonstrated the effectiveness of Realistic Mathematics Education (RME) in enhancing students' mathematical conceptual understanding, most research has focused on the general application of RME without integrating specific manipulative media. Similarly, studies on algebra tiles as a concrete manipulative have proven their benefits in visualizing concepts of linear equations, but their use is often implemented separately from a systematic instructional framework like RME. Consequently, there is a scarcity of in-depth research examining how the integration of RME and algebra tile media can be synergistic in addressing difficulties in conceptual understanding, particularly in the topic of Linear Equations in One Variable at the junior high school level. This research gap forms the novelty of the present study, which is to examine the effectiveness of implementing RME enriched with algebra tile media to build students' conceptual understanding in a more meaningful and sustainable manner.

METHOD

This study employed a quantitative method with a Quasi-Experimental design, specifically the Nonequivalent Control Group Design. This design involved two groups: an experimental group, which received instruction using the Realistic Mathematics Education (RME) approach assisted with algebra tile media, and a control group, which received conventional instruction. Both groups were given a pretest and a posttest to measure their mathematical conceptual understanding ability before and after the treatment.

The research population consisted of all seventh-grade students at Public Junior High School (SMP Negeri) 8 South Halmahera in the 2022/2023 academic year, consisting of five classes. The sample was selected using a purposive sampling technique based on the equivalence of initial ability and class accessibility, resulting in two classes with 20 students each.

The research instrument was a test in the form of five essay questions developed based on indicators of conceptual understanding. These indicators included the ability to: (1) restate a concept, (2) classify objects according to a concept, (3) provide examples and non-examples, (4) present a concept in various forms of representation, and (5) apply the concept in problem-solving. The instrument was validated by three experts and piloted to obtain empirical validity and reliability, which was calculated using Cronbach's Alpha.

The research procedure consisted of: (1) a preparation stage, involving the development of learning materials, preparation of algebra tile media, and instrument testing; (2) an implementation stage, consisting of the administration of the pretest, the delivery of treatments according to the learning design, and the administration of the posttest; and (3) a data analysis stage.

Data analysis was conducted through normality tests (Shapiro-Wilk) and homogeneity tests (Levene's Test) as prerequisite tests. The hypothesis was tested using an independent samples t-test to determine the difference in the average score of conceptual understanding ability between the experimental and control groups. Furthermore, the N-Gain score was calculated to measure the improvement in conceptual understanding ability, and the effect size (Cohen's d) was calculated to determine the magnitude of the treatment's effect.

RESULTS AND DISCUSSION

This study obtained quantitative data derived from the pretest and posttest results of students' mathematical conceptual understanding ability. The test results for students'

mathematical conceptual understanding are presented in the descriptive statistics shown in Table 1.

Table 1. Descriptive statistics of students' mathematical conceptual understanding ability

Descriptive statistics	Control class		Experimental Class	
	Pretest	Posttest	Pretest	Posttest
N	20	20	20	20
Minimum	10	40	10	60
Maximum	40	70	40	95
Mean	24.00	56.75	22.50	78.50
Std. Deviation	9.119	7.993	9.665	9.191

Based on Table 1, it can be explained that both groups had an equal number of subjects (20) at each measurement stage (pretest and posttest), indicating no subject attrition and providing a good balance for comparing results between the control and experimental groups.

In the initial measurement (pretest), both groups showed an identical score range with a minimum of 10 and a maximum of 40, confirming that the initial conditions of the two groups were comparable. After the treatment, a striking difference emerged: the control group had a score range of 40-70, while the experimental group achieved a range of 60-95. This indicates that the treatment not only increased the group's average but also boosted the performance of all subjects. Notably, the lowest-performing subject in the experimental group (60) still scored higher than the lowest-performing subject in the control group (40).

The mean pretest scores for both groups were nearly identical (Control: 24.00; Experimental: 22.50), ensuring an equivalent starting point. In the posttest, a significant increase was observed: the control group reached 56.75, and the experimental group reached 78.50, showing an effectiveness difference of 21.75 points due to the treatment. The standard deviation reveals an interesting pattern: the control group experienced a decrease in variability from 9.119 to 7.993 (data became more homogeneous), while the experimental group remained relatively stable, from 9.665 to 9.191. This indicates that the treatment provided consistent improvement across all ability levels of the subjects.

Based on the descriptive data of the conceptual understanding test results, prerequisite tests were conducted prior to inferential statistical analysis. The results of the normality test are presented in Table 2.

Table 2. Results of normality test for students' mathematical conceptual understanding ability

Class	Test	Shapiro-wilk			Conclusion
		Statistic	df	Sig.	
Experimental	Pretest	0.937	20	0.213	Normal
	Posttest	0.951	20	0.389	Normal
Control	Pretest	0.923	20	0.111	Normal
	Posttest	0.967	20	0.694	Normal

Based on the results of the Shapiro-Wilk normality test presented in Table 2 above, it can be concluded that all data in this study are normally distributed, as all obtained significance values are greater than 0.05 ($\alpha = 0.05$). This indicates that the assumption of normality for parametric statistical analysis has been met, allowing the researchers to proceed with analysis using parametric tests such as the t-test or ANOVA to compare the effectiveness of the treatment between the experimental and control groups. The results of the homogeneity of variance test using Levene's Test are shown in Table 3.

Based on Table 3, the results of the homogeneity of variances test using Levene's Test show that the assumption of homoscedasticity is met for both measurement conditions in this study. The significance values for both the pretest (0.664) and posttest (0.585) consistently exceed the critical value of $\alpha = 0.05$. This indicates that the null hypothesis of variance equality between

groups fails to be rejected; therefore, the variances of the experimental and control groups are not significantly different in either the initial or final measurement.

Table 3. Results of homogeneity test for students' mathematical conceptual understanding ability

	Levene Statistic	df1	df2	Sig.
Pretest	0.191	1	38	0.664
Posttest	0.303	1	38	0.585

The next step was to test the effect of applying the RME approach using algebra tile media on students' mathematical conceptual understanding ability. The research hypotheses were formulated as follows:

- H_0: There is no effect of applying RME using algebra tile media on students' mathematical conceptual understanding ability.
- H_1: There is an effect of applying RME using algebra tile media on students' mathematical conceptual understanding ability.

A summary of the parametric statistical test results (Independent Sample t-test) is presented in Table 4 and was used for decision-making regarding the application of the RME approach using algebra tile media.

Table 4. Summary of independent sample t-test results for mathematical conceptual understanding ability

	t-test for Equality of Means						
	t	df	Sig. (2-tailed	Mean difference	Std. error difference	95% Confidence Interval of the Difference	
						Lower	Upper
Equal variances assumed	7.986	38	0.000	21.750	2.724	16.236	27.264

The results of the independent t-test for equality of means show a highly significant difference between the experimental and control groups. With the assumption of equal variances, a t-value of 7.986 was obtained with 38 degrees of freedom, resulting in a two-tailed significance value of 0.000. This significance value is far below the critical value of $\alpha = 0.05$, indicating that the null hypothesis of no mean difference between groups can be rejected with a very high degree of confidence. The mean difference between the two groups is 21.750 with a standard error of 2.724. The 95% confidence interval for the mean difference ranges from 16.236 to 27.264.

Following the independent sample t-test, which confirmed a significant effect of applying RME using algebra tile media, an effect size test was conducted using Cohen's d. The analysis yielded a Cohen's d value of 2.526, indicating that the application of RME using algebra tile media has a very large effect on students' mathematical conceptual understanding ability.

Subsequently, an N-Gain analysis was performed to determine the magnitude of improvement after the treatment. The results of the normalized N-Gain calculation are presented in Table 5.

Table 5. Results of normalized n-gain calculation

Value	Learning Outcome	Statistical Test	Result
N-Gain Score	Control Class	Minimum	0.27
		Maximum	0.54
		Mean	0.4308
		Std. Deviation	0.08149
	Experimental Class	Minimum	0.38
		Maximum	0.92
		Mean	0.7237
		Std. Deviation	0.12476

Descriptive analysis of the N-Gain scores shows a substantial difference in learning achievement between the control and experimental groups. The control group had an N-Gain score ranging from a minimum of 0.27 to a maximum of 0.54, with a mean of 0.4308. The experimental group showed superior performance with a range from 0.38 to 0.92 and a mean of 0.7237. According to standard interpretation criteria, the control group's gain falls into the "medium" category ($0.3 < g \leq 0.7$), while the experimental group's gain falls into the "high" category ($g > 0.7$). The effectiveness of the approach was also analyzed by calculating the N-Gain as a percentage (%); the results are presented in Table 6.

Table 6. Results of n-gain calculation (%)

Value	Learning Outcome	Statistical Test	Result
N-Gain Score	Control Class	Minimum	26.67
		Maximum	53.85
		Mean	43.08
		Std. Deviation	8.15
	Experimental Class	Minimum	38.46
		Maximum	92.31
		Mean	72.37
		Std. Deviation	12.48

The analysis of the percentage N-Gain scores confirms the significant disparity in learning improvement. The mean N-Gain for the control group was 43.08%, classified as "medium" effectiveness. In contrast, the experimental group achieved a mean N-Gain of 72.37%, which is classified as "high" effectiveness. This provides strong empirical evidence that the RME approach using algebra tile media was not only statistically significant but also highly effective in practice for enhancing students' mathematical conceptual understanding.

The results of this study indicate that students' mathematical conceptual understanding at the beginning of the lesson (pretest) between the control and experimental groups was relatively equal, as indicated by nearly identical average scores and identical ranges. This confirms that the differences in achievement that emerged in the posttest were due primarily to the treatment provided, rather than differences in initial conditions.

After the learning intervention using the Realistic Mathematics Education (RME) approach, using the algebra board as a medium, the experimental group demonstrated significantly greater achievement gains than the control group. The experimental group's posttest average reached 78.50, while the control group's average was only 56.75, representing a difference of 21.75 points. An independent t-test confirmed a highly significant difference ($t = 7.986$; $p < 0.001$), with a very large effect size (Cohen's $d = 2.526$). These findings confirm that RME, using concrete media, can have a substantial impact on improving mathematical conceptual understanding.

The effectiveness of RME revealed in this study aligns with various previous studies. A meta-analysis conducted by Tamur et al. (2020) reported that the implementation of RME yielded a high average effect size of 1.104, indicating that this approach is effective in improving students' mathematical abilities. Similar results were also reported by Juandi et al. (2022), who found an effect size of 0.97 in various international studies, and by Isnaintri et al. (2024), who found an effect size of 0.95 in the Indonesian educational context. Therefore, the findings of this study, which yielded a higher effect size ($d = 2.526$), strengthen evidence that the use of algebra boards can optimize the potential of RME in mathematics learning.

Further N-Gain analysis showed that the experimental group achieved an average score of 0.72 (high category), while the control group only achieved 0.43 (moderate category). This difference of 29.29 points demonstrates that the intervention is not only statistically significant but also practically meaningful. These findings are consistent with research by Alim et al. (2023), who reported a 0.57 increase in N-Gain through RME, and Estimurti and Sriwihartati (2024), who demonstrated a high level of improvement when RME was combined with contextual learning media.

These research findings also align with the results of a study by Rangkuti et al. (2024), which demonstrated that RME was effective in improving mathematical conceptual understanding in fractions with a significance level of p = 0.018. Furthermore, research by Ariffah and Rusnilawati (2023), and Ariati et al. (2023) demonstrated that RME significantly improved students' mathematical reasoning skills. Thus, the implementation of RME with the aid of an algebra board not only proved effective in the context of this study but also aligns with international literature regarding the effectiveness of contextual approaches in mathematics learning.

Theoretically, these results can be explained by the main principles of RME, which emphasize the connection of mathematical concepts to everyday life and the use of concrete models to build abstract understanding (Freudenthal, 1991). In this study, the algebra board served as a representational medium that bridged contextual experiences with formal symbolism, enabling students to construct a more meaningful and in-depth understanding of concepts.

Thus, the results of this study provide strong empirical evidence that the RME approach, supported by the algebra board, not only improves average student achievement but also narrows achievement gaps and ensures consistent improvement across various ability levels. These findings reinforce the recommendation that the RME approach be further developed in mathematics learning practices, particularly through the integration of concrete media relevant to students' contexts.

CONCLUSIONS

The implementation of the Realistic Mathematics Education (RME) approach utilizing an algebra board has been demonstrated to have a substantial impact on the mathematical conceptual understanding of seventh-grade students at SMP N 8 South Halmahera. The results of the independent sample t-test indicate a significant effect, with a p-value (Sig. 2-tailed) of 0.000 ($p < 0.05$). This finding substantiates the substantial impact of the RME approach implemented using an algebra board on students' mathematical conceptual understanding. Additionally, the Effect Size calculation yielded a d value of 2.52, indicating that this approach exhibits a "large" effect.

The implementation of the Realistic Mathematics Education (RME) approach utilizing an algebra board significantly enhanced the mathematical conceptual comprehension of seventh-grade students enrolled at SMP N 8 South Halmahera. The analysis of the N-gain scores revealed an average score of 0.72, substantiating the efficacy of the RME approach employing an algebra board in augmenting students' mathematical conceptual understanding. The average N-Gain percentage of 71.84% indicates that the effectiveness of this approach in enhancing students' mathematical conceptual understanding is deemed "fairly effective."

This study presents several limitations that warrant careful consideration. Firstly, the study sample was restricted to two classes from a single institution, resulting in a relatively small sample size. Consequently, generalizing the findings to a broader population necessitates caution. Secondly, the curriculum covered only Linear Equations in One Variable, rendering the results potentially unsuitable for other mathematical subjects. Thirdly, conceptual understanding was assessed solely through essay tests based on the indicators of the National Council of Teachers of Mathematics (NCTM), thereby overlooking other dimensions such as students' attitudes, motivation, and mathematical communication skills. Fourthly, the treatment duration was relatively short, precluding a comprehensive evaluation of the long-term impact of implementing algebra board-assisted RME on the retention of conceptual understanding.

The findings of this study offer significant implications for mathematics teaching practices in junior high schools. Educators can consider integrating algebra board media into the Research-Based Methodology (RME) approach as a strategy to facilitate students' transition from concrete to symbolic representations in a more meaningful manner. This implementation can assist in overcoming students' challenges in comprehending linear equation concepts and promote contextual learning. For policymakers, the results of this study can serve as a foundation for developing teacher training programs or providing concrete learning media pertinent to the curriculum. Simultaneously, for future researchers, the limitations present opportunities for

conducting further studies with larger sample sizes, broader coverage, diverse measurement techniques, and long-term observation of effects. This approach will enable a more comprehensive understanding of the efficacy of manipulative media-assisted RME.

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