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# The Effect of Realistic Mathematics Education (RME) Learning based STEM Activity on Students' Mathematical Representation Abilities

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**Abstract**
The low ability of students to transform mathematical problems into verbal, visual, or symbolic representations approached that teacher centered learning and the lack of linking the material to real contexts. This research investigates how Realistic Mathematics Education (RME) integrated with STEM activities influences students' ability to represent mathematical concepts. This research adopted a quantitative approach with a quasi-experimental pretest-posttest control group design to evaluate the effect of the implemented learning approach. The sampling of participants was carried out through cluster random sampling. The instrument employed for data collection comprised interview guides, observation sheets, validation forms, and test items designed to measure students' mathematical representation ability. Data collection was carried out through observation, interviews, and mathematical representation ability tests. Data were analyzed using normality tests, homogeneity tests, independent sample t-tests, paired sample t-tests, N-gain scores, and Cohen's d effect size. The results follow that RME learning-based STEM activities in the experimental group was better with a high N-gain score (0.73) compared to the control class with a medium N-gain score (0.54). The Cohen's d effect size analysis yielded a value of 1.43, falling into the "very large" category. These results confirm that RME instruction combined with STEM activities successfully enhances students' mathematical representation ability.

**Keywords:** RME Learning, STEM Activity, Mathematical Representation Ability

## 1. Introduction

Mathematics is a fundamental science that serves as the foundation for various academic disciplines therefore, improving it is crucial for achieving established proficiency standards (Siswanto, 2024). However, the finding of the 2022 Program for International Student Assessment (PISA) survey, the average mathematics literacy score for Indonesian students was only 366 points, falling below the OECD average of 472 points (OECD, 2023). The weakness in literacy often stems from students' inability to reconstruct a concept through various mathematical models. According to the NCTM (National Council of Teachers of Mathematics), one of the fundamental abilities that students must master to support this ability is the ability to represent mathematical concepts (NCTM, 2000). This competency is closely linked to problem-solving, as students must construct appropriate representations to arrive at correct solutions (Supriadi et al., 2023). Conceptually, mathematical representations facilitate students in expressing ideas through various interconnected forms to find solutions to mathematical problems (Tamba, W. M. M et al., 2021).

Schifter & Russell (2022) classified mathematical representations into three primary domains: numerical representations in the form of sentences (verbal), visually depicted representations (graphs, diagrams, or tables), and symbolic representations that enable students to understand concepts based on their interpretation. According to Fitri et al. (2025), mastery of this representational ability is crucial for students to deeply understand lesson content and effectively solve problems. Problems that appear difficult and complex can become easier to understand if mathematical strategies and representations are applied appropriately according to the characteristics of the problem at hand (Putra et al., 2023). Without adequate representational ability, students will not only struggle to grasp the core of mathematical material but will also be hindered in understanding instructions and solving problems correctly.

Nevertheless, the urgency of developing mathematical representation ability has not yet been reflected in actual classroom conditions. Preliminary observations and interviews with a mathematics teacher and students at MTs Negeri Kota Magelang revealed that students continue to experience difficulties in transforming mathematical problems into appropriate visual, symbolic, or graphical forms. These difficulties were further substantiated by baseline test results, which yielded an average score of 44.25. This weakness in representation corresponds to the result of Suningsih et al. (2021) who revealed that students struggle to represent a given problem and face difficulties in the problem-solving process. Similar findings by Nurhadida et al. (2025) indicate that students' mathematical representation ability in solving PISA-type questions remain relatively low, based on an average percentage of 35.06%, where students struggle to translate information into verbal, symbolic, and visual forms. This gap is primarily influenced by a learning process that remains teacher-centered, as well as a lack of connection between the material and students' real-world experiences. As a result, mathematics instruction tends to be viewed as abstract and lacking in meaning for students. In light of this, mathematical representation ability needs to be given serious attention in the classroom so that students can grasp mathematical concepts more easily and solve problems effectively.

In response to these challenges, a reform oriented toward conceptual meaningfulness is necessary. One of the most promising alternatives is the adoption of Realistic Mathematics Education (RME). This approach emerges as a promising alternative because it has a distinctive characteristic: the use of real-world contexts to initiate learning activities. The concept of RME was developed by Freudenthal, who posited that mathematics should be viewed as a form of human activity (Maslihah et al., 2021). This means that mathematics is not viewed as knowledge ready to be imparted to students, but rather as a concept that students need to discover and construct for themselves through a process of mathematization within meaningful real-life contexts.

Several studies have confirmed the benefits of implementing RME in mathematics instruction. Research by Puteri & Priatna (2025) demonstrated that the implementation of RME positively influenced students' ability to represents mathematical concepts. Corroborating these findings, a meta-analysis by Hadistian et al. (2025) revealed that RME exerts a significant effect in improving problem-solving ability. This improvement, in turn, positively affects students' learning independence, which further contributes to the increase of their mathematical representation ability (Haranti et al., 2025). Consequently, RME holds substantial potential for fostering students' mathematical representation ability.

To optimize the effectiveness of RME instruction in developing mathematical representation ability, this study introduces an innovative approach through the implementation of STEM activities. These activities are systematically designed for each stage of RME instruction. The term STEM originated from the initialism SMET, coined by the U.S National Science Foundation (NSF) in the 1990s and subsequently revised to STEM by the NSF administrator in 2001 (Li et al., 2025). In practice, STEM activities present students with relevant real-world problems, guide them in integrating science, technology, engineering, and mathematics, and provide adequate collaborative discussion, practical experimentation, and iterative design processes (Hinon & Polyiem, 2025). STEM activities can be utilized in learning as a strategy that links theory with practice, encouraging students not only to grasp concepts but are also able to apply them in real-life contexts. According to Noor & Malichatin (2025), STEM activities incorporate the Engineering Design Process (EDP), which includes ask, plan, create and improve. A previous study by Nugroho (2024) established that STEM-based learning can enhance students' mathematical representation ability. Accordingly, STEM-activity-learning holds strong potential for improving students' mathematical representation ability.

Although numerous studies on RME and STEM have been conducted and have proven effective in improving students' various mathematical ability, research that specifically integrates STEM activities into every stage of the RME learning process to enhance mathematical representation ability remains limited. Most previous studies have implemented RME and STEM separately or have only integrated STEM elements into certain learning activities. In addition, studies examining this integration in the context of relations and functions are still rare. Therefore, this study offers a novel approach by integrating STEM activities into every stage of the RME learning process to enhance students' mathematical representation ability.

This study, term of 'based' signifies that the entire learning sequence from planning and implementation to assessment is constructed and directed according to STEM principles rather than merely incorporating isolated STEM elements (Roehrig et al., 2021). Thus, RME learning-based STEM activities emphasizes interdisciplinary connections through contextual activities, real-world problem-solving, and integrated application of concepts. Students are not only expected to understand concepts theoretically but are actively guided to design solutions, conduct experiments, analyze data, and make decisions grounded in scientific and mathematical reasoning. Consequently, this study aimed to examine the impact of RME learning-based STEM activities on students' mathematical representation ability, and the expectation of providing new insights into the application of STEM elements in RME to enhance mathematical representation ability in a more contextual and practical manner.

## 2. Methods

Quasi-experimental method was conducted with a pretest-posttest control group design. Two groups were involved: the experimental group and the control group. The experimental class received intervention in the form of RME learning-based STEM activities, while the control class received direct instruction. The design of research for both classes used the experimental design as described by Sugiyono (2017), which is presented in Table 1.

**Table 1**. Research Design

| Classes | Pretest | Treatment | Posttest |
|---|---|---|---|
| Experiment | $O_1$ | X | $O_2$ |
| Control | $O_3$ | - | $O_4$ |

Noted:
$O_1$: Pretest for the experimental class
$O_2$: Posttest for the experimental class
$O_3$: Pretest for the control class
$O_4$: Posttest for the control class
X : RME learning-based STEM activity

The population comprised all 86 Grade VIII students of MTs Negeri Kota Magelang for the 2025/2026 academic year. Sampling was conducted using cluster random sampling. The resulting sample consisted of Class VIII-A (n=22) as the experimental group and Class VIII-B (n=21) as the control group.

This study employed several data collection included observation, interviews, and test. Observation was conducted at two points: a preliminary observation and a classroom learning implementation observation. Interview was conducted with mathematics teachers and students to obtain information to be used a supporting data in the study. Test instruments in this study consisted of pretest and posttest questions, each consist of three essay questions that include verbal, visual, and symbolic representation, which had undergone a validation process by experts. The questions were then pilot-tested on students at MTs Negeri Kota Magelang who had already studied the material on relations and functions. The pretest pilot was conducted in Class IX A, and the posttest pilot was conducted in Class IX B. The pilot study aimed to determine the validity, reliability, difficulty level, and discriminating power of each item (Retnawati, 2016). Results of these trials were then used as the basis for determining the instrument's suitability before it was used in the research data collection process.

The data were analyzed through descriptive and inferential method. Descriptive analysis was used to describe the characteristics of the data through measures such as the mean, maximum, and minimum values, and standard deviation. Inferential analysis was carried out using SPSS software to formulated research hypotheses. Before the hypotheses were tested, it was first ensured that the data met the basic statistical assumptions through normality test and homogeneity tests using Levene's Test. Once all assumptions were satisfied, hypothesis testing proceeded using the independent sample t-test to assess differences between the two classes and the paired sample t-test for examine within-group changes from pretest to posttest. The N-gain score test was applied to measure students' improvement in mathematical representation ability following the implementation of the instruction. Additionally, Cohen's d effect size was calculated to estimate the magnitude of the effect of the intervention.

## 3. Result and Discussion

### 3.1. Analysis of the Practice Test Questions

#### Item Validity

Validity analysis was conducted to evaluate the appropriateness of each test item by correlating individual item scores with total scores derived from the pilot test data. The output show that all pretest and posttest test items meet the validity criteria. Therefore, the test is suitable for use because a test item is considered valid if $r_{xy} > r_{table}$ (Yusup, 2018). An overview of the item validity results presents in Table 2.

**Table 2**. **Item Validity Test**

| | Item | $r_{xy}$ | $r_{table}$ | Criteria |
|---|---|---|---|---|
| *Pretest* | 1 | 0.862 | 0.423 | valid |
| | 2 | 0.848 | | valid |
| | 3 | 0.858 | | valid |
| | 4 | 0.825 | | valid |
| *Posttest* | 1 | 0.896 | 0.444 | valid |
| | 2 | 0.863 | | valid |
| | 3 | 0.834 | | valid |
| | 4 | 0.755 | | valid |

#### Item Reliability

A test instrument is considered reliable if the data it produces is consistent each time the measurement is conducted. Reliability was measured using Cronbach's Alpha coefficient with the KR-20 formula (Sundayana, 2018). According on the findings of analysis, the reliability coefficient for the pretest items was 0.857 and for the posttest items was 0.847. Thus, both instruments fall within the very high reliability criteria. The detailed results are over view in the table below.

**Table 3.** Reliability Testing of Pretest and Posttest Items

| Test | $r_{11}$ | Criteria |
|---|---|---|
| *Pretest* | 0.857 | very high |
| *Posttest* | 0.847 | very high |

**Item Difficulty Level**

Difficulty level is an indicator that shows how easy or difficult a test item is for students. The difficulty level of each test item is classified into several categories based on established criteria (Arikunto, 2018). Based on the analysis results, all pretest and posttest items fell into the easy and moderate categories. A summary of the analysis results for the difficulty level of each test item is over view in the following table.

**Table 4**. Level of Difficulty

| Test | Item | Difficulty Index | Interpretation |
|---|---|---|---|
| *Pretest* | 1 | 0.708 | easy |
| | 2 | 0.659 | medium |
| | 3 | 0.542 | medium |
| | 4 | 0.576 | medium |
| *Posttest* | 1 | 0.679 | medium |
| | 2 | 0.621 | medium |
| | 3 | 0.592 | medium |
| | 4 | 0.754 | easy |

**Discriminatory Power**

Discriminatory power is an indicator that measures a test item's ability to discriminate between student's high ability (top group) and student's low-ability (bottom group). The discriminating power of each test item is classified according to established criteria (Arikunto, 2018). The analysis results show that all pretest and posttest items have discriminatory power in the "adequate" category. A summary of the discriminating power results for each test item is reported in Table 5.

**Table 5.** Item Discrimination Index

| Test | Item | Distinctiveness Index | Interpretation |
|---|---|---|---|
| *Pretest* | 1 | 0.220 | adequate |
| | 2 | 0.303 | adequate |
| | 3 | 0.265 | adequate |
| | 4 | 0.227 | adequate |
| *Posttest* | 1 | 0.303 | adequate |
| | 2 | 0.242 | adequate |
| | 3 | 0.267 | adequate |
| | 4 | 0.275 | adequate |

### 3.2. Results of Descriptive Analysis the Initial Data

The pretest scores for both the experimental and control classes showed relatively low averages. Based on the descriptive analysis, the control class achieved of 42.64 in pretest mean score with 6.167 of standard deviation. While, the experimental class achieved 43.56 of pretest mean score with a standard deviation of 5.380. The results of the descriptive analysis of the pretest data are presented in Table 6.

**Table 6.** Descriptive Statistics of Pretest Data

| Classes | N | Min | Max | Sum | Average | Std.Deviation |
|---|---|---|---|---|---|---|
| Control | 21 | 33.33 | 55.56 | 895.45 | 42.64 | 6.167 |
| Experiment | 22 | 36.11 | 52.78 | 958.33 | 43.56 | 5.380 |

Prior to inferential analysis of the pretest results, initial data analysis was employed comprising normality tests, homogeneity tests, and an independent sample t-test. The Shapiro-Wilk test was selected for normality assessment given that the sample consisted of fewer than 50 students (Mishra et al., 2019). A summary of test results is reported in Table 7.

**Table 7.** Preliminary Data Analysis Results

| Classes | Shapiro Wilk | | | Homogeneity Test Levene's Statistic | | Independent Sample t-Test | Decision |
|---|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | Sig. | Sig. | |
| Control | 0.944 | 21 | 0.262 | 0.154 | 0.696 | 0.605 | $H_0$ accepted |
| Experiment | 0.939 | 22 | 0.187 | 0.154 | | | |

According to the pretest normality test, the significance values obtained were 0.262 for the control class and 0.187 for the experimental class; both classes therefore exhibited a normal data distribution. The homogeneity test yielded a significance value of 0.696 ($p > 0.05$), showing that the variances of the two classes were homogeneous. The independent sample t-test produced a significance value of 0.605 ($p > 0.05$), confirming that the two classes did not differ significantly in their initial mathematical representation ability.

### 3.3. Final Data Analysis Results

Development in mathematical representation ability was analyzed by comparing pretest and posttest scores. According to the normality test of the posttest data, significance values for the experimental class and the control class were 0.506 and 0.414, respectively, thus the data for both classes were confirmed to be normally distributed. As for the homogeneity test, significance value of 0.472 ($p > 0.05$) was obtained. Therefore, the null hypothesis ($H_0$) was accepted, meaning that both classes have homogeneous variances. The complete results of these tests showed in this following table.

**Table 8.** Results of the Normality and Homogeneity Tests for Posttest Data

| Classes | Shapiro Wilk | | | Homogeneity Test Levene's Statistic | | Decision |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | Sig. | |
| Control | 0.955 | 21 | 0.414 | 0.527 | 0.472 | $H_0$ accepted |
| Experiment | 0.961 | 22 | 0.506 | | | |

**Hypothesis 1. Improvement in Mathematical Representation Ability in the Experimental Class and Control Class**

The paired sample t-test was used to test the significance of the increase in scores from the pretest to the posttest in each class. The results showed that the control class experienced a significant increase with a t-value of -15.734, a mean difference of -31.302, and a significance level (2-tailed) of 0.000 ($p < 0.05$). Meanwhile, the experimental class also experienced a significant increase with a t-value of -22.786, a larger mean difference of -41.415, and a significance level (2-tailed) of 0.000 ($p < 0.05$). Therefore, null hypothesis ($H_0$) was rejected, concluding that both the control and experimental classes experienced a significant increase in scores from the pretest to the posttest. The complete results of the paired samplet-test are presented in the Table 9.

**Table 9.** Paired Sample T-Test

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) | Decision |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | | |
| | | | | | Lower | Upper | | | | |
| Pair 1 | Pre_Control - Post_Control | -31.302 | 9.117 | 1.989 | -35.452 | -27.152 | -15.734 | 20 | .000 | $H_0$ rejected |
| Pair 2 | Pre_Exp - Post_Exp | -41.415 | 8.525 | 1.818 | -45.194 | -37.635 | -22.786 | 21 | .000 | $H_0$ rejected |

**Hypothesis 2. Differences in Mathematical Representation Ability Between the Experimental and Control Classes**

The satisfaction of normality and homogeneity assumptions in the posttest data provided the basis for proceeding with parametric statistical testing. Based on the results of the independent sample t-test, the significance value obtained was 0.000 ($p < 0.05$). The posttest results also show that the experiment class achieved an average of 84.98, which is higher than that of the control class (73.94). Thus, the null hypothesis ($H_0$) was rejected. This means that the implementation of RME learning-based STEM activities was proven to be able to increase students' mathematical representation ability more significantly than the class that used the direct instruction method. The findings of the test are presented in Table 10.

**Tabel 10.** Independent Sample T-Test

| Classes | N | Average | Sig. | Decision |
|---|---|---|---|---|
| Control | 21 | 73.94 | 0.000 | $H_0$ rejected |
| Experiment | 22 | 84.98 | | |

**N-Gain Score and Effect Size Cohen's d**

The N-gain score analysis conducted to compare the magnitude of development in mathematical representation ability across the two classes. The results of the analysis are presented in Table 11.

**Tabel 11**. N-Gain Score Result

| Classes | N-Gain Score | Category |
|---|---|---|
| Control | 0.54 | Medium |
| Experiment | 0.73 | High |

Based on the table, the control class obtained an N-gain score of 0.54 as medium categorized, while the experimental class reached a higher N-gain score of 0.73 as a high categorized. Furthermore, the Cohen's d effect size analysis yielded a value of 1.43, falling into the "very large" category ($d > 0.8$). This indicates that the difference in mathematical representation ability between the experimental and control classes was not only statistically significant but also had a substantial practical impact in the field.

## 3.4. Discussion

**RME Learning based STEM Activities in the Experimental Class**

The result of research indicates that students' mathematical representation ability in the experimental class improved from the pre-instruction phase to the post-instructional phase, as evidenced by an increase in the average score from 43.56 on the pretest to 84.97 on the posttest, yielding an N-gain score of 0.73 which falls into the high category. These findings suggest that the instructional approach implemented in the experimental class on that links contextual problem with STEM activities can enhance students' representation abilities. This substantial improvement can be attributed to the RME instructional steps integrated with STEM activities, as presented in the student worksheet. Through a systematically arranged sequence of instructions and guiding questions, the worksheets lead students to construct their understanding based on concrete experience gained through group experiments. This finding aligns by Hutapea (2022) which suggest that real-life contexts can serve as a foundation for mathematics learning while fostering active student participation. Through this process, students are able to transform their contextual experience into various forms of mathematical representation, namely verbal, visual, and symbolic. An illustrative example of the worksheets is presented in Figure 1.

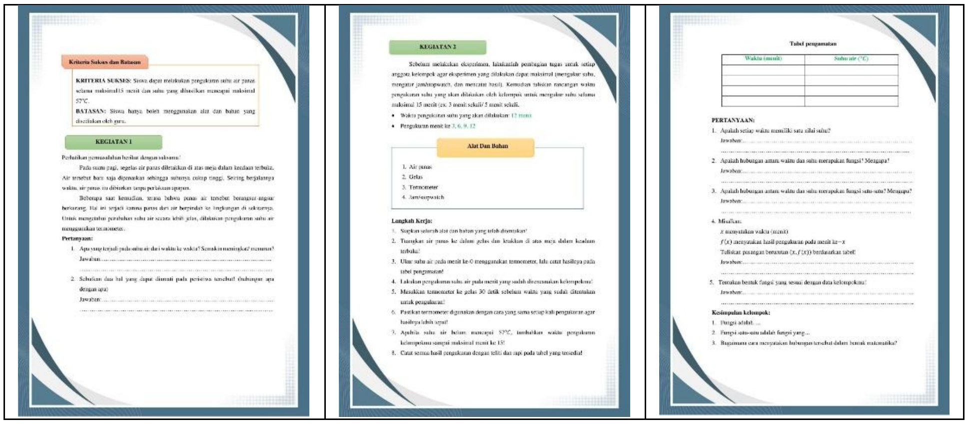


**Figure 1**. RME Learning based STEM Activity Worksheet

Figure 1 presents the worksheet on relations and functions in the context of hot water temperature change. The implementation of STEM activities in this learning process is explained through the Engineering Design Process (EDP), which comprises the stages of ask, plan, create, and improve, thereby distributing cognitive load across each stage of RME. The stage of understanding the contextual problem (ask) is reflected in the narrative of the problem concerning hot water whose temperature gradually decreases, accompanied by initial questions guiding students to identify the pattern of temperature change and the relationship between the observed variables. The stage of explaining the contextual problem (ask-plan) is realized through instructions for group task division and the independent design of measurement time intervals by each group, resulting in distinct experimental design across groups. The stage of solving the problem (create-improve) is carried out through experimental work steps, ranging from preparing tools and materials, and measuring the initial temperature to recording the results periodically. At this stage, students may adjust the experiment by extending the measurement time up to the limit set by the teacher if the resulting temperature has not yet met the EDP success criteria. Subsequently, the stage of comparing and discussing answers (improve) is facilitated through a series of reflective questions concerning the relationship between time and temperature based on each group's empirical data. Unlike the previous stage, which focused on the data collection process, the refinement at this stage lies in students understanding and representation through the evaluation and comparison of results across groups. Finally, the stage of drawing conclusions (improve) is where students together with the teacher, formulate the concept under study based on their experimental experience. This concluding stage also strengthens students' mathematical representation ability to comprehensively understand the relationships between concepts (Zentgraf & Prediger, 2024). This series of stage, which gradually builds experience, can lead to an improvement in students' mathematical representation ability.

The improvement in students' mathematical representation ability in the experimental class can be explained through the cognitive mechanism that occurred throughout the stages of learning. In the initial stage, as students collected temperature data directly through experimentation, the information they processed was concrete and meaningful; as suggested by Wakhata et al. (2023), their cognitive capacity was not burdened by the effort of comprehending an abstract situation but remained available for recognizing the mathematical pattern underlying the data. This available cognitive capacity was then utilized to carry out the process of vertical mathematization, which occurs when students transform observational data into more formal representations (Nguyen & Nguyen, 2024). The internal representation formed at this stage was subsequently tested and reinforced through social interaction, as students externalized their mathematical ideas in verbal, symbolic, and visual forms to be compare them with the result of other groups. This process of externalization and negotiation of meaning aligns with Vygotsky's Theory of cognitive development through social interaction (Arafah et al., 2023). In the context of this study, this was realized as students questioned and clarified one another's representation across groups, such that the resulting understanding was not formed individually but was enriched through group discussion. This is supported by Izzati & Listiyani (2026), who not that structured mathematical discussion encourages students to employ various forms of representation when communicating their ideas. Accordingly, students' mathematical representation abilities developed cumulatively, beginning with concrete experience that reduced cognitive load, continuing through the process of abstraction, and being reinforced through collective reflection. These interrelated mechanisms illustrate how RME instruction integrated with STEM activities can systematically scaffold the development of students' mathematical representation abilities.

A number of previous studies support the findings of this research. Putra et al., 2024) found that RME learning, developed through research and development using the ADDIE model, produced a significant improvement in students' mathematical representation ability. This finding is consistent with the variable examined in the present study-namely, mathematical representation ability and with the use of RME as the foundation of the learning process. However, the present study employed a quantitative quasi-experimental method, in which RME learning was integrated with STEM activities. Another study was conducted by Putri et al. (2025), reported that students who underwent STEM-based learning exhibited a greater improvement in mathematical representation ability than those who received direct instruction. This finding aligns with the present research in terms of the ability measured and the use of STEM activities; however, in that study, STEM was applied independently without being combined with RME, such that the contextual problems given to students were not explicitly constructed through the stages of RME learning. Rahmania & Shodikin (2025), similarly integrated RME within a STEM framework, and their findings are consistent with the present study in terms of the effort to combine RME and STEM into a single, cohesive learning framework. However, their study focused on creative thinking ability using a descriptive qualitative design and did not employ the EDP as the basis for integration. By contrast, the present study explicitly combines the stages of RME with STEM activities within a quasi-experimental design to measure students' mathematical representation ability.

**Direct Instruction in the Control Class**

Based on the research findings, the mathematical representation ability of students in the control class, which implemented direct instruction method, showed an improvement from before to after the learning process. This is evidenced by an increase in the average score from 42.64 on the pretest to 73.94 on the posttest, yielding an N-gain score of 0.54, classified as a moderate category. This improvement indicates that the learning implemented in the control class had an effect on students' mathematical representation ability, although the improvement was lower than that of the experimental class.

This can be attributed to the characteristics of direct instruction, which tends to be dominated by teacher-centered explanation. In this approach, the teacher first explains the concept of relations and functions along with the corresponding solution procedures, after which students replicate the given examples through similar exercises. This process helps students understand basic procedures, allowing their mathematical representation ability to improve to some extent. However, because most learning activities are centered on the teacher's explanations, students are rarely required to independently transform verbal representations into pictures, tables, graphs, or mathematical models. As a result, flexibility in mathematical representation develops more slowly than in the experimental class. Students are also given less practice in presenting mathematical problems through various forms of representation, particularly in contextual settings. This is consistent with the findings of Syahril et al. (2021), who found that students often experience difficulty when confronted with contextual problems, one contributing factor is insufficient practice in solving non-routine, contextual tasks. This limited practice in translating between representations during direct instruction leaves students unaccustomed to constructing solution steps systematically and explicitly.

**Differences in the Improvement of Mathematical Representation Ability Between the Experimental and Control Classes**

The independent sample t-test yielded a significance value of 0.000 ($p < 0.05$), indicating a significant difference in the improvement of mathematical representation ability between the experimental and control classes. This finding is reinforced by the N-gain score test, which showed that the average posttest score of the experimental class was 0.73 (high category), higher than that of the control class at 0.54 (medium-high category). In addition, the calculation of Cohen's d value of 1.43, falling into the very large category, indicates that the difference between the two classes was not only statistically significant but also of substantial practical significance.

This finding can be explained by the primary characteristic of RME, which places contextual problems as the foundation of the learning process. Through RME, students are guided to develop a more meaningful understanding of mathematical concepts by utilizing real-world contexts relevant to their everyday experiences (Batul et al., 2022). This process gives students the opportunity to explore mathematical concepts embedded within real-world problems, such that the understanding constructed reflects conceptual and in-depth comprehension rather than mere procedural memorization (Ningsi et al., 2024). As a result, students are able to independently construct understanding and connect various concepts, contributing to the improvement of their mathematical representation ability. The STEM activities integrated into this learning process have also proven to contribute to the improvement of students' mathematical representation ability. This occurs because STEM not only integrates science, technology, engineering, and mathematics, but is also designed to build students' interdisciplinary thinking skills in solving real-world problems (Nugraha et al., 2024). Through these STEM activities, students are guided to think critically and acquire new knowledge through hands-on learning experiences (Hakiki et al., 2022). Accordingly, RME integrated with STEM activities not only strengthens students' conceptual understanding but also fosters critical thinking, problem-solving, and creativity.

Theoretically, this finding confirms that mathematical representation ability develops cumulatively and gradually, enriching the understanding of how RME and STEM can be integrated structurally rather than merely thematically. Educationally, this finding suggests that improvement in mathematical representation ability can be achieved through the refinement of instructional design for existing material, without requiring changes to the curriculum structure-underscoring the importance of ongoing teacher training in designing instruction that integrates science-technology contexts into mathematics. Practically, RME learning-based STEM activities can serve as an alternative instructional approach for teachers seeking to improve students' mathematical representation ability, by adapting the stages of the Engineering Design Process (EDP) into the design of student worksheets in accordance with the context and resources available at their respective schools.

## 4. Conclusion

This study found that RME learning-based STEM activities has a significant effect on students' mathematical representation ability compared to students who receive direct instruction. This learning experience helps students connect mathematical concepts to real-life situations and can support the development of their mathematical representation ability. For classroom practice, this approach offers a mathematics teacher, especially when teaching topics that require various forms of mathematical representation, by encouraging active participation and deeper conceptual understanding. Furthermore, this study provides empirical evidence the effect of RME learning-based STEM activity on students' mathematical representation abilities, particularly regarding relations and function. Future research is recommended to examine the application of RME learning-based STEM activity across various educational levels and mathematical topics, as well as to involve larger samples to strengthen the generalizability of the research findings.

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