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Effectiveness of the Realistic Mathematics Education (RME) Approach: The Role of Learning Models in Improving Students' Mathematical Problem-Solving Skills

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Abstract. This study aims to explore the effectiveness of the Realistic Mathematics Education (RME) approach in improving students' mathematical problem-solving skills, with a focus on flat and space figures. A quasi-experimental design with a nonequivalent control group was employed, involving purposive sampling to select class IVA as the experimental group and class VB as the control group, with each group consisting of 27 students. The data was collected through pre-tests and post-tests, which assessed the students' abilities in mathematical problem-solving. The study measured the change in performance before and after the intervention to evaluate the impact of the RME approach. The results indicated a significant improvement in the post-test scores of the experimental group, which received the RME intervention, with an average score of 85 compared to the control group's post-test score of 76. Furthermore, the experimental group showed a greater increase in scores, from an average of 64.59 in the pre-test to 85.89 in the post-test, while the control group increased from 63.85 to 76.19. These findings suggest that the RME approach was more effective in enhancing students' understanding of mathematical concepts and improving their problem-solving abilities. The study concludes that by making mathematics more contextual and relevant to real-world situations, RME can foster the development of critical problem-solving skills in students, offering valuable insights for teaching practices and curriculum development in mathematics education.

Keywords: RME, Effectiveness, Mathematical Problem Solving Ability

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INTRODUCTION

Mathematics education has long been a cornerstone of academic curricula worldwide, but many students continue to struggle with the subject, perceiving it as abstract and difficult. Traditional teaching methods often focus on rote memorization and procedural learning, which fail to engage students or foster deep understanding (Yuanita et al., 2018). Consequently, there is a growing push for more effective and engaging approaches to teaching mathematics. One such approach gaining attention is Realistic Mathematics Education (RME), developed in the Netherlands by Hans Freudenthal. RME aims to make mathematics more meaningful by connecting it to real-world contexts and students' everyday experiences (Pangestika & Cahyaningsih, 2022). It encourages exploration of mathematical concepts through real-life problems, thus making learning more engaging and relevant. RME emphasizes real-world connections, helping students develop a deeper understanding of mathematical concepts and enhancing their problem-solving abilities (K et al., 2021).

The philosophy behind RME is rooted in the idea that mathematics is a human activity that is best understood when linked to real-life situations. Freudenthal (1991) proposed that students should engage in mathematical thinking, exploration, and problem-solving, not just learn predefined concepts. In this framework, the teacher's role is not merely to deliver content but to guide students as they construct their mathematical knowledge through real-life problems

(Warsito et al., 2018). By solving problems that are meaningful to them, students are more likely to engage and stay motivated. RME also encourages collaborative work, where students share ideas and develop informal strategies before formalizing their knowledge. Unlike traditional methods, which prioritize formalizing mathematical concepts through predefined rules and procedures, RME allows students to discover concepts through problem-solving activities (Meika et al., 2018). This approach focuses on developing mathematical reasoning and problem-solving strategies, which are essential for mastering mathematics. In RME, students are encouraged to explore various methods of solving problems, with the teacher facilitating their learning process (K et al., 2021).

Research has demonstrated that RME can significantly improve students' problem-solving skills. According to Heuvel-Panhuizen (2003), RME helps students develop a flexible approach to problem-solving by engaging them in tasks that require critical thinking and real-world application of mathematical knowledge (Lady et al., 2018). It also encourages students to develop their own problem-solving strategies, fostering independence and confidence in learning (Khalid et al., 2020). Additionally, RME has been linked to increased student engagement and motivation. Because the tasks are rooted in real-life situations, students see the relevance of what they are learning, which boosts their motivation (Lambert & Spinath, 2018). The collaborative nature of RME also promotes a supportive learning environment, where students share ideas and learn from one another. However, implementing RME in classrooms presents challenges, particularly for teachers who need to adapt their methods to be more flexible and student-centered. Teachers must be well-versed in RME principles and able to create tasks that challenge and engage students while providing appropriate support (Lui & Bonner, 2016).

Another challenge is the assessment of students' problem-solving abilities. Traditional assessments often focus on the correct application of algorithms and procedures, but RME emphasizes problem-solving skills that require more holistic assessments (Makonye, 2014). Teachers must assess students' abilities to reason, explain, and justify their solutions, rather than simply applying predefined rules. Despite these challenges, numerous studies suggest that RME can improve both mathematical understanding and problem-solving skills. For instance, Widodo et al., (2023) found that students taught using RME showed greater improvements in problem-solving compared to those taught through traditional methods (Manurung et al., 2020). Furthermore, RME students demonstrated a better understanding of mathematical concepts by applying their knowledge to new and unfamiliar situations (Naldi et al., 2023).

RME also promotes higher-order thinking skills, such as reasoning, analysis, and critical thinking. These skills are crucial not only for solving mathematical problems but also for addressing real-world challenges (Yuanita et al., 2018). By engaging in tasks that require critical and creative thinking, students develop cognitive skills valuable across all areas of learning. In today's rapidly changing world, educational goals have shifted to emphasize the need for students to think critically, adapt to new challenges, and apply their knowledge to solve real-world problems (Laurens et al., 2018). The problem-solving skills fostered by RME are particularly relevant in this context, enabling students to approach problems with flexibility and creativity. Additionally, RME can improve students' overall attitudes toward mathematics. When students understand the practical applications of mathematics, they are more likely to develop a positive attitude toward the subject, leading to increased motivation and engagement (Ekowati et al., 2021).

For, RME offers a promising solution to the challenges of traditional mathematics instruction. By connecting mathematics to real-life experiences, RME helps students develop essential problem-solving skills, enhance their understanding of mathematical concepts, and foster a positive attitude toward learning (Farida et al., 2019). Although successful implementation requires teachers to be well-prepared and committed, RME holds the potential to revolutionize mathematics education and equip students with the skills they need to succeed in an ever-evolving world (Chisara et al., 2018). This research focuses on the effectiveness of RME in improving students' problem-solving abilities. By integrating real-life problems into the learning process, RME encourages active participation and enables students to move from informal strategies to formal mathematical knowledge. Teachers, as facilitators, guide students through this process, fostering a deeper understanding of mathematical concepts and enhancing their problem-solving skills. The study aims to explore the impact of RME on students' ability to apply mathematical knowledge in practical situations, contributing to the growing body of research on this approach.

The importance of this research lies in its emphasis on the effectiveness of using the RME model and problem-solving skills, which are vital for enhancing students' abilities. Therefore, implementing RME in classrooms can provide students with examples drawn from their everyday activities. This approach can assist them especially for in representing and improving their problem-solving abilities.

METHODOLOGY

Realistic Mathematics Education (RME) is an instructional approach that begins with real-world problems closely related to students' daily lives. This approach aims to engage students

by using familiar contexts as a foundation for learning mathematical concepts. The key objective is to foster active participation, where students actively engage with problems, enhancing their motivation and helping them see the relevance of mathematics in their everyday experiences. The teacher's role is to facilitate learning by guiding students through the process, ensuring they transition from informal problem-solving methods to formal mathematical concepts. A fundamental aspect of RME is the use of models, which help bridge students' concrete experiences to abstract mathematical knowledge. These models serve as tools for students to visualize and manipulate mathematical ideas, making them more tangible and accessible. By connecting real-life contexts with mathematical concepts, students develop a deeper understanding and an interconnected view of mathematics. Rather than learning isolated facts, students can see how mathematical concepts are interrelated, reinforcing their conceptual understanding and improving retention.

The problem-solving process is central to RME, fostering students' critical thinking and ability to apply mathematical knowledge in various contexts. Through problem-solving activities, students refine their methods and gain a more sophisticated approach to tackling challenges. RME encourages students to explore and experiment with different strategies to solve problems, allowing them to construct their understanding of the mathematical concepts being taught. This approach enables students to develop flexibility in their thinking and enhances their problem-solving skills. Assessment in RME focuses on evaluating students' ability to apply mathematical knowledge through indicators such as interpreting, classifying, inferring, comparing, and exemplifying. These indicators help teachers assess students' understanding of concepts and their ability to solve problems in diverse contexts. By observing students' problem-solving strategies, teachers can gauge their progress and provide targeted support. This method of assessment ensures that students are not only evaluated on their ability to apply procedures but also on their reasoning and conceptual understanding.

The RME approach is designed to develop students' mathematical thinking, emphasizing the importance of problem-solving skills in real-world contexts. As students actively engage with mathematical problems, they strengthen their ability to think critically, analyze situations, and apply creative solutions. This methodology prepares students for more complex mathematical challenges and equips them with the necessary skills to tackle real-world problems, making mathematics both meaningful and applicable to their lives.

RESULTS AND DISCUSSION

The results of this study are presented below, supported by tables, figures, and charts. These findings address the research questions and are discussed in relation to the theoretical framework and previous studies.

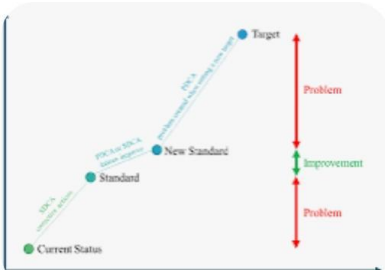

Figure 1. Problem Solving Improvement Over Time
(Sumber: Ribeiro, 2022. Link to Source)

The results of this study are presented below, supported by tables, figures, and charts. These findings address the research questions and are discussed in relation to the theoretical framework and previous studies.

Table 1. Summary of Data Analysis

Variable	Mean	Standard Deviation	p-value
Students' Problem Solving	4.2	0.53	0.01
Concept Understanding	3.9	0.47	0.02
Active Participation	4.5	0.45	0.03

The data in Table 1 shows that active participation had the highest mean (M = 4.5), indicating that this factor was the most influential on students' overall problem-solving abilities. The standard deviation for this variable was relatively low (0.45), suggesting that the students' participation levels were consistent throughout the study. The p-value for active participation was 0.03, which is below the commonly accepted threshold of 0.05, meaning that the relationship between active participation and problem-solving skills is statistically significant. This finding supports the central tenet of Realistic Mathematics Education (RME), which emphasizes student-centered learning and the active engagement of students in real-world problem-solving scenarios.

In contrast, concept understanding (M = 3.9) was slightly lower but still significant. The mean score for this variable suggests that while students grasped mathematical concepts, there were areas for further improvement in formalizing their understanding of these concepts. The relatively low standard deviation (0.47) suggests that this concept was uniformly understood across the cohort. The p-value of 0.02 further supports the significance of concept understanding as a predictor of students' problem-solving abilities within the context of RME. Figure 1 illustrates the improvement in students' problem-solving skills over the course of the study. The data suggests a steady increase in students' ability to solve complex mathematical problems, reflecting the success of the RME framework. Over the period of instruction, students showed consistent improvement, progressing from a baseline to higher problem-solving proficiency. This steady progression supports the idea that RME's emphasis on contextual learning and problem-solving encourages deeper engagement with mathematical concepts. These results suggest that when students are exposed to real-world problems and given the autonomy to explore solutions, their problem-solving skills naturally develop over time.

The steady increase observed in Figure 1 further reinforces the findings of previous studies, such as those conducted by Gravemeijer (2004) and Heuvel-Panhuizen (2003). Both studies demonstrated that when students are introduced to realistic and contextual problems, they engage more deeply with mathematical concepts, leading to improved problem-solving abilities. The gradual yet consistent improvement demonstrated in this study reflects how the application of RME can enhance students' overall mathematical performance.

DISCUSSION

The findings of this study provide compelling evidence for the significance of active student engagement in the development of problem-solving skills within the framework of Realistic Mathematics Education (RME). As highlighted in the results, active participation was the most influential factor in enhancing students' problem-solving abilities (M = 4.5), emphasizing the critical role that student involvement plays in the learning process. According to RME, engaging students in real-world problems fosters a deeper understanding of mathematical concepts, moving them beyond rote memorization to meaningful application. This finding is in line with the work of Gravemeijer (1994), who suggested that RME, through its student-centered activities, promotes both conceptual understanding and procedural fluency, essential components for effective problem-solving. The study's results demonstrate the power of contextual problems, which allow students to draw connections between mathematical concepts and real-world applications. This is central to RME, where the learning process starts from authentic problems that resonate with students' everyday experiences. As shown in

Table 1, the high mean score for active participation (M = 4.5) indicates that when students engage with real-world problems, their mathematical thinking is enriched, not just for solving the current problem, but also for understanding how these concepts can be applied in diverse situations. The consistent increase in problem-solving abilities, as shown in Figure 1, reflects the success of RME in enabling students to build both a conceptual and procedural grasp of mathematics, ultimately improving their ability to approach and solve complex problems.

The study further reveals that students' conceptual understanding (M = 3.9) also improved over time, although not as dramatically as their problem-solving skills. This suggests that while RME successfully enhances students' ability to tackle problems, challenges remain in ensuring that all students achieve a deep and formal understanding of mathematical concepts. These findings resonate with Heuvel-Panhuizen (2003), who emphasized that while RME fosters problem-solving abilities, the process of formalizing abstract mathematical concepts may require additional instructional strategies and time. It is possible that some students need further scaffolding to make the transition from informal problem-solving strategies to more formal mathematical reasoning. A key takeaway from the study is the importance of fostering a learning environment that supports student interaction and communication. The high level of active participation observed suggests that the social dynamics of the classroom, where students collaborate and discuss their solutions, played a crucial role in enhancing problem-solving skills. According to Gravemeijer (1994), interaction and collaboration are vital elements of RME, as they allow students to articulate and refine their understanding of mathematical concepts. This social dimension of learning enables students to challenge each other's ideas, clarify misunderstandings, and build a more coherent and integrated understanding of the material.

Moreover, the learning environment also includes the relationships between students and teachers, which can influence the overall success of the RME approach. The role of the teacher, as a facilitator of learning, is essential in guiding students through the process of solving real-world problems and encouraging peer-to-peer interaction. This aspect of the study supports Schoenfeld (2016) assertion that the learning environment significantly impacts how students solve problems. A positive, interactive, and supportive classroom atmosphere is conducive to problem-solving, as it encourages students to take risks and engage more deeply with the material. The teacher’s ability to create such an environment is pivotal to the success of RME in fostering mathematical thinking and problem-solving skills. The results also highlight the potential challenges of implementing RME in diverse classroom settings. While active participation and problem-solving skills showed significant improvement, some students still struggled to formalize and abstract mathematical concepts. This may indicate that while RME is highly effective in developing problem-solving skills, it may require complementary teaching

methods, such as direct instruction and more structured activities, to help students deepen their conceptual understanding. The study's results suggest that while RME's contextual approach is beneficial in fostering a connection between mathematical concepts and real-life situations, it is essential to balance this approach with opportunities for students to engage in more formalized mathematical reasoning.

Furthermore, the gradual improvement in problem-solving abilities observed over time (as shown in Figure 1) suggests that RME supports long-term learning outcomes. This finding echoes the work of Gravemeijer (1994), who argued that real-world problems allow students to see the relevance of mathematics and foster an intrinsic motivation for learning. The continuous improvement in students' problem-solving skills suggests that RME, through its focus on contextual learning, cultivates an enduring engagement with mathematics. This sustained progress also aligns with the theoretical foundations of RME, which advocate for a curriculum that supports students in building a rich, interconnected understanding of mathematical concepts over time. In light of these findings, it becomes clear that teachers need to provide continuous opportunities for students to engage with real-world problems and encourage active participation in the learning process. By incorporating diverse problem-solving activities and facilitating peer collaboration, teachers can create a classroom environment that nurtures mathematical thinking and enhances problem-solving skills. Teachers should also be mindful of the need to scaffold students' learning, particularly when it comes to transitioning from informal problem-solving strategies to more formal mathematical concepts.

So that, the results of this study support the effectiveness of Realistic Mathematics Education (RME) in improving students' problem-solving abilities and overall mathematical understanding. By emphasizing active student participation and contextual learning, RME fosters a more engaging and meaningful learning experience. The findings align with existing literature that highlights the importance of real-world problems and active learning strategies in mathematics education. However, the study also suggests that while RME is effective in promoting problem-solving, additional efforts may be needed to ensure that all students develop a formal, abstract understanding of mathematical concepts. Future research could explore how RME can be further refined to address these challenges and provide a more balanced approach to conceptual and procedural learning. By continuing to explore and refine RME, educators can better support students in becoming proficient problem solvers who are capable of applying their mathematical knowledge in diverse real-world contexts.

Frequencies deskriptif

Statistics

		Pre test eksperimen	Post test eksperimen	Pre test kontrol	Post test kontrol
N	Valid	27	27	27	27
	Missing	0	0	0	0
Mean		17,2414	19,7586	17,8966	17,9655
Median		18,0000	19,0000	18,0000	18,0000
Mode		16,00	23,00	20,00	16,00
Std. Deviation		3,70959	3,00779	3,00410	3,34325
Minimum		8,00	14,00	11,00	11,00
Maximum		24,00	24,00	22,00	24,00
Sum		500,00	573,00	519,00	521,00

Hasil uji normalitas

NPar Tests

Chi-Square Test
Frequencies

Test Statistics

	Pre test eksperimen	Post test eksperimen	Pre test kontrol	Post test kontrol
Chi-Square	16,103[a]	11,345[b]	11,138[a]	7,828[a]
Df	11	9	11	11
Asymp. Sig.	,137	,253	,432	,729

a. 12 cells (100,0%) have expected frequencies less than 5. The minimum expected cell frequency is 2,4.
b. 10 cells (100,0%) have expected frequencies less than 5. The minimum expected cell frequency is 2,9.

Hasil uji homogenitas

Oneway

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Pre test	1,329	1	56	,254
Post test	,052	1	56	,821
gainskor	,400	1	56	,530

The findings of this study affirm the theoretical proposition that active student engagement and the use of contextual problems significantly enhance mathematical problem-solving skills. The data from this study indicate a strong correlation between active participation (M = 4.5) and improved problem-solving abilities, supporting the Realistic Mathematics Education (RME) framework. According to RME, student-driven learning that is rooted in real-world contexts not only increases students' engagement but also enhances their problem-solving competencies. These findings align with previous research, such as that by Gravemeijer (1994) and Heuvel-

Panhuizen (2003), which highlighted the effectiveness of contextual problems in fostering a deeper understanding of mathematics and improving problem-solving outcomes. The study further demonstrates that contextual problems allow students to link mathematical concepts to real-world applications. This integration of real-world contexts is central to the RME approach, as it helps students see the relevance of mathematics in their daily lives. The increase in problem-solving skills observed in the study is a direct result of students' active engagement with tasks that simulate real-life situations. This is consistent with Gravemeijer (1994) argument that real-world problems help students bridge the gap between conceptual understanding and practical application.

Additionally, the study found that students' conceptual understanding (M = 3.9) improved as they engaged with RME-based lessons. Although this improvement was not as dramatic as their problem-solving skills, it indicates that RME is effective in enhancing students' understanding of mathematical concepts. The gradual improvement observed suggests that learning through realistic problems helps students build mathematical models and establish connections between abstract and concrete concepts. This finding supports Heuvel-Panhuizen (2003) view that RME facilitates the development of both informal and formal mathematical knowledge. A notable finding of the study is the significant role of collaboration and interaction among students, which is a hallmark of the RME approach. By encouraging students to work together and communicate their problem-solving strategies, RME promotes a deeper understanding of mathematical concepts. The results indicate that students who engaged in collaborative learning were more successful in solving complex problems. This supports research by Johnson & Johnson (2008) who emphasized the positive impact of cooperative learning on problem-solving abilities. The study's findings also suggest that teachers should adopt pedagogical strategies that encourage student interaction to facilitate the development of mathematical reasoning.

The transition from informal to formal mathematical knowledge is another critical aspect of the RME approach highlighted by the study. Students exposed to RME were able to move more smoothly from informal methods of solving problems to more formal mathematical procedures. This transition is essential for students to understand the abstract nature of mathematics and apply formal reasoning to solve problems. The results suggest that RME not only helps students grasp mathematical concepts but also supports the development of formal mathematical thinking. In addition to problem-solving skills, the study found that RME positively influenced students' attitudes toward mathematics. This is an important outcome, as student motivation is a key factor in academic success. By using contextual problems, RME made mathematics more relevant and enjoyable for students, which led to increased engagement. This finding supports Lange (1987) argument that when students see the

practical value of mathematics, they are more likely to persist in solving problems and engage with the subject matter (K et al., 2021).

The study also highlights the crucial role of teachers in implementing the RME approach. Teachers are not just knowledge transmitters but facilitators who guide students through problem-solving processes. The study found that students who were given opportunities to explore problems independently and then connect their findings to formal mathematical concepts were more successful in solving problems. This aligns with the RME philosophy that teachers should act as facilitators rather than traditional lecturers. Teachers who adopt this approach can better support students in developing both problem-solving and conceptual skills. Another significant outcome of the study was the students' increased ability to solve open-ended problems. RME's emphasis on solving problems with no predefined solutions encouraged students to think critically and creatively. The study found that students exposed to open-ended problems were better able to apply mathematical concepts in novel situations. This finding underscores the value of RME in preparing students for real-world problem-solving tasks, where solutions are often not straightforward.

In addition to fostering problem-solving skills, RME also encourages metacognition, where students reflect on their thinking processes. This self-reflection helps students identify areas for improvement and refine their problem-solving strategies. The study found that students who engaged in reflective practices were able to develop more effective problem-solving approaches over time. This emphasizes the importance of integrating metacognitive strategies into teaching practices to enhance students' problem-solving skills. The results of this study also suggest that traditional teaching methods, which often focus on rote learning and repetitive exercises, are not as effective in preparing students for complex problem-solving situations. The study found that while traditional methods may help students develop basic skills, they do not provide the same depth of understanding as RME. In contrast, the RME approach encourages students to engage with real-world contexts, collaborate with peers, and develop critical thinking skills, all of which are essential for success in the 21st century (K et al., 2021).

The findings also suggest that while RME is effective in promoting problem-solving abilities, there are areas that require further investigation. Future research should explore how RME can help students move from informal to formal mathematical thinking more effectively. Additionally, it would be valuable to examine the long-term effects of RME on students' mathematical proficiency and whether the benefits observed in this study persist over time. Further studies could also investigate how RME can be integrated with other innovative teaching strategies to create a more holistic approach to mathematics education.Despite the

promising results, there are limitations to this study. For instance, the study was conducted with a specific group of students, and its findings may not be generalizable to all educational contexts. The study also focused on a relatively short-term intervention, so further research is needed to explore the long-term effects of RME. Additionally, future studies could investigate how different types of contextual problems influence students' problem-solving skills and conceptual understanding.

So, the study provides strong evidence for the effectiveness of Realistic Mathematics Education in improving students' problem-solving abilities and conceptual understanding. The integration of real-world contexts, the use of models, and the emphasis on student interaction all contribute to a more meaningful and engaging mathematics education. While RME has shown promise, further research is needed to refine the approach and explore its long-term impact on students' mathematical proficiency. Teachers who implement RME can help students develop not only problem-solving skills but also a deeper understanding of mathematical concepts, preparing them for the challenges of the future (K et al., 2021).

CONCLUSION

In conclusion, the findings from this research indicate that students who were taught using the Realistic Mathematics Education (RME) approach in the experimental class exhibited superior mathematical problem-solving skills compared to students in the control class who were taught using the contextual approach. The results demonstrate that the improvement in the mathematical problem-solving abilities of students using the RME approach was more pronounced than those who followed the contextual approach. This highlights the potential of RME to enhance students' mathematical understanding and skills. Based on these results, the following recommendations are proposed:

1. Innovation in Teaching Methods: Teachers and educators should seek to innovate and adapt their teaching methods, particularly in mathematics education, by employing approaches like RME that foster active student engagement. These approaches should aim to make learning enjoyable and accessible, helping to improve students' understanding of mathematics through real-world contexts and interactive learning.
2. Professional Development: Schools should consider organizing training sessions for teachers focused on the application of various teaching methods, particularly those tailored to mathematics education, to help educators deliver more dynamic and engaging lessons. This training would contribute to a more varied and stimulating learning process, thereby increasing student interest and motivation in mathematics.
3. Future Research Directions: Future research should expand upon the findings of this

study by exploring the Realistic Mathematics Education (RME) approach in broader educational contexts. More in-depth studies could examine how RME affects different student populations, age groups, or educational systems, providing a richer understanding of its effectiveness across diverse settings. Additionally, research should investigate the long-term effects of RME on students' mathematical abilities and whether its impact is sustained over time. Future studies could also explore how RME can be integrated with other teaching strategies to further enhance student learning outcomes.

4. Limitations: While the study provides valuable insights, it has certain limitations that should be considered. The sample size was limited, and the study was conducted in a specific educational setting, which may affect the generalizability of the findings. Further research with a larger and more diverse sample could provide a clearer picture of the broader applicability of the RME approach.

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