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Realistic Mathematics Education Approach with the Assistance of Augmented Reality Media to Improve Elementary School Students' Mathematics Learning Outcomes

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Abstract: Mathematics is a subject that every student must master. However, mathematics remains a traumatic experience for most students. This impacts students' low mathematics learning outcomes. This study aims to improve elementary school students' mathematics learning outcomes using a realistic mathematics education approach assisted by augmented reality media. This study is a classroom action research consisting of three cycles. Each cycle goes through four stages of activity: planning, action, observation, and reflection. The subjects of this study were fourth-grade students of SD Negeri 69 Banda Aceh. Data for this study were collected using observation and test techniques. Observations were used to measure teacher and student learning activities, while tests were used to measure improvements in students' mathematics learning outcomes. The results of the study indicate that the realistic mathematics education approach assisted by augmented reality media can improve elementary school students' mathematics learning outcomes. This can be seen in the average scores on the test results which show an increase in each cycle, namely 44.57 (pre-cycle), 63.07 (first cycle), 75.66 (second cycle), and 87.35 (third cycle). Based on this, the realistic mathematics education approach assisted by augmented reality media can be used as an alternative to solve the problem of low mathematics learning outcomes of students in elementary schools.

Keywords: Realistic mathematics education, augmented reality, learning media, mathematics.

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INTRODUCTION

Mathematics is a fundamental discipline that plays a crucial role in developing students' critical and logical thinking skills. However, many elementary school students struggle to grasp mathematical concepts, resulting in low learning outcomes. The primary contributing factor is a conventional learning approach that lacks real-life context.

The low mathematics learning outcomes of elementary school students constitute a significant challenge in education. Data from the Programme for International Student Assessment (PISA) indicates that Indonesian students rank among the lowest in mathematics proficiency. This indicates the need for more effective and innovative learning approaches to address this issue.

One proposed solution is the implementation of the Realistic Mathematics Education (RME) approach, which emphasizes meaningful mathematics learning through real-world contexts. This approach allows students to actively construct their knowledge, deepening their understanding of mathematics.

In the digital age, technologies such as Augmented Reality (AR) have become potential tools to enhance student interaction and understanding of learning materials. AR can provide three-dimensional visualizations of mathematical objects, which are difficult to explain through conventional methods. The integration of the RME approach with AR media is expected to create a more interactive and contextual learning environment.

This study aims to test the effectiveness of the AR-assisted RME approach in improving mathematics learning outcomes of fourth-grade students at SD Negeri 69 Banda Aceh. Furthermore, this study explores the impact of this approach on student and teacher learning activities. The results are expected to provide theoretical and practical contributions to the world of education, both by enriching the literature and serving as a reference for educational practitioners.

This study employed a Classroom Action Research (CAR) design consisting of three cycles. Each cycle encompasses planning, action, observation, and reflection. Data were collected through observation and testing techniques to measure improvements in student learning outcomes. SD Negeri 69 Banda Aceh was chosen as the research location because it represents the problem of low mathematics learning outcomes, a common problem faced by many elementary schools in Indonesia.

Several previous studies have examined the implementation of RME or AR separately, but few have combined the two. This study attempts to fill this gap by exploring the synergy between the two approaches. The theoretical framework of this study is based on constructivism theory and context-based learning theory, which provide a logical foundation for combining RME and AR.

The main research question in this study is how effective the AR-assisted RME approach is in improving students' mathematics learning outcomes, and how it impacts student and teacher learning activities. The research hypothesis is that the AR-assisted RME approach will significantly improve students' mathematics learning outcomes compared to conventional methods.

This study has limitations, namely, its focus only on fourth-grade students at SD Negeri 69 Banda Aceh and specific mathematics material. Therefore, generalizations of the results must be made with caution. This article is structured systematically, including an introduction, literature review, methodology, results and discussion, conclusions, and recommendations, to provide a comprehensive understanding of this research.

METHODS

This study used a Classroom Action Research (CAR) design to test the effectiveness of the Realistic Mathematics Education (RME) approach, supported by Augmented Reality (AR), in improving students' mathematics learning outcomes. The CAR approach was chosen because it allows researchers to make continuous improvements through a cycle of actions (Kemmis & McTaggart, 1988). The research was conducted in three cycles, each consisting of four main stages: planning, action, observation, and reflection. The research subjects were 30 fourth-grade students at SD Negeri 69 Banda Aceh. The research location was selected based on the problem of low mathematics learning outcomes, a common problem faced by many elementary schools in Indonesia. In addition to students, classroom teachers were also involved as partners in the implementation of the action to ensure the approach could be adapted to everyday learning contexts. The research instruments used included a learning outcome test in the form of multiple-choice and essay questions validated by experts to measure student understanding, an observation sheet to document student and teacher activities during the learning process, and semi-

structured interviews with students and teachers to explore their perceptions of the AR-assisted RME approach.

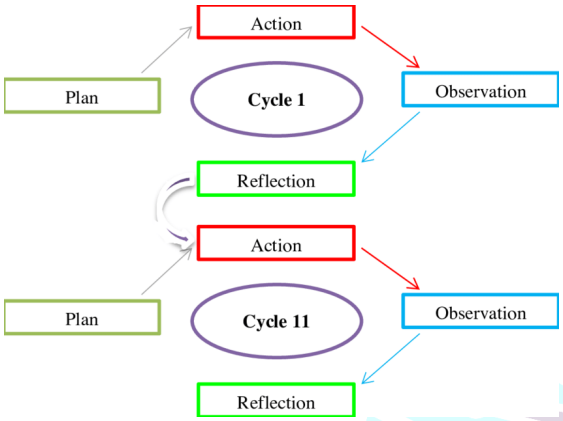

Figure 1. *Research Design*

The research procedure began with a preparation phase, where the researcher conducted a needs analysis through initial observations and document review. Next, AR media was developed with a team of technology experts and mathematics teachers to ensure its suitability for the learning material. In the implementation phase, each CAR cycle was implemented through planning, action, observation, and reflection. Planning included developing a lesson plan (RPP) that integrated RME and AR. Actions were implemented according to the RPP, utilizing AR media to visualize mathematical concepts. Observations included recording and analyzing classroom dynamics and student responses. Reflection was conducted to evaluate the strengths and weaknesses of the actions for improvement in the next cycle.

Data analysis was conducted quantitatively and qualitatively. Quantitative data from tests were analyzed using descriptive statistics and t-tests to identify significant differences before and after the intervention. Meanwhile, qualitative data from observations and interviews were analyzed thematically to identify emerging patterns and themes. Data validity was ensured through triangulation of sources and methods, as well as peer review by fellow researchers. Furthermore, the researcher maintained research ethics by ensuring the confidentiality of participants' identities and obtaining approval from the school and parents.

RESULTS

This classroom action research was conducted over three cycles to evaluate the effectiveness of implementing the Realistic Mathematics Education (RME) approach supported by Augmented Reality (AR) media in improving mathematics learning outcomes among fourth-grade students at SD Negeri 69 Banda Aceh. Each cycle consisted of four phases: planning, implementation, observation, and reflection. The primary focus in data collection was on classroom observations and students' test results at the end of each cycle.

At the initial stage (pre-cycle), a diagnostic test was administered to assess the students' prior knowledge. The results of this test showed that the average student score was only 44.57 out of a maximum score of 100. This finding indicates that most students were still struggling with basic mathematical concepts when taught using conventional methods, especially on the topic of fractions, which was the main focus of this study.

Following the implementation of the RME approach integrated with AR in Cycle I, the average student score increased to 63.07. This improvement indicates a positive impact of the intervention, although most students still fell within the "satisfactory" category. Based on classroom observations, student engagement during the learning

process also improved, particularly when AR media were used to visualize mathematical concepts in real-life contexts.

Several challenges were encountered in Cycle I, including students' unfamiliarity with operating AR devices and time constraints in exploring the materials. Consequently, Cycle II included improvements such as brief preliminary training on how to use the AR tools and reinforcement of RME through group-based problem-solving activities rooted in real-life scenarios.

The results from Cycle II showed a significant improvement in learning outcomes, with the average test score increasing to 75.66. Additionally, observation data indicated that students were more enthusiastic and actively engaged in learning activities. The use of AR media helped students grasp the connections between mathematical concepts and everyday situations, such as using fractions in cooking or food distribution.

During Cycle III, the instructional strategies were further refined by integrating reflective tasks and group discussions to enhance conceptual understanding. AR media were also employed more effectively through systematically designed, contextualized learning scenarios. This approach proved highly effective in encouraging active student participation.

The test results from Cycle III indicated an average score of 87.35, suggesting that most students had reached a high level of proficiency. All students showed improvement compared to the previous cycle, with the majority scoring above 80. This confirms that the integration of the RME approach with AR media significantly contributes to improved mathematics learning outcomes.

In addition to the test results, students' learning activities also improved steadily. In Cycle I, student activity was categorized as "sufficient," with an average observation score of 68. In Cycle II, this score rose to 80, and in Cycle III, it reached 92. Students demonstrated more consistent engagement in listening to the teacher's explanations, participating in peer discussions, and using AR media to solve problems.

Teacher performance also improved from cycle to cycle. Teachers became more adept at linking real-life contexts to mathematical concepts, guiding class discussions, and facilitating the use of AR media. The teacher observation score increased from 70 (Cycle I) to 85 (Cycle II), and reached 95 in Cycle III.

The improvement in student outcomes and classroom engagement indicates that the RME approach supported by AR media is effective in creating meaningful and contextual learning experiences. Students were not only able to understand abstract mathematical concepts but also apply them in real-world contexts visualized through technology.

Further data analysis showed that the success of this approach was also influenced by increased student motivation. During the learning process, students were more interested and focused on the material presented due to the visual and interactive elements of the AR media. This accelerated their conceptual understanding and reduced anxiety toward mathematics.

Active student participation throughout the learning process also improved from cycle to cycle. In Cycle I, only 55% of students actively asked questions and participated in discussions. This figure rose to 75% in Cycle II and reached 90% in Cycle III. This engagement reflects the success of the instructional strategy in fostering an interactive and enjoyable learning environment.

Significant changes in students' learning outcomes were also reflected in their conceptual understanding. For instance, students who previously could only define fractions were, by the end of Cycle III, able to solve contextual problems involving fraction operations accurately and logically. This demonstrates deep and applicable learning achievements.

Interviews with several students supported the quantitative findings. Most students stated that the use of AR media made learning mathematics more enjoyable and easier to understand. Some even reported that they had grown to like mathematics more than before because they could visualize and manipulate virtual objects.

Data gathered from various instruments—tests, observations, and interviews confirmed that the application of the RME approach supported by AR media significantly improved students' mathematics learning outcomes. The observed improvements were not only quantitative, in the form of higher scores, but also qualitative, in terms of increased motivation, participation, and conceptual understanding.

DISCUSSION

The findings of this study indicate that integrating the Realistic Mathematics Education (RME) approach with Augmented Reality (AR) media significantly improved students' mathematics learning outcomes. This improvement aligns with previous studies that highlight the positive impact of context-based learning in helping students construct mathematical concepts meaningfully (Wijaya, 2016).

In the pre-cycle phase, students demonstrated a relatively low level of understanding, as indicated by an average score of 44.57. This supports research by Kurniawan et al. (2020), which found that traditional methods often fail to engage students in meaningful mathematical thinking, resulting in surface-level understanding and low achievement.

The gradual increase in test scores across the cycles—from 63.07 in Cycle I to 87.35 in Cycle III suggests that the combination of RME and AR media not only supports conceptual comprehension but also enhances students' motivation and interest in learning mathematics. According to Sari and Rosnawati (2018), motivation is a key driver for student engagement and performance in mathematics.

The use of RME contextualized mathematical content into real-life situations. By connecting abstract mathematical ideas to daily experiences, students developed a more intuitive understanding. Gravemeijer and Doorman (2018) emphasized that RME allows learners to build models of thinking grounded in real-world problems, which can later be formalized into mathematical structures.

The AR media, on the other hand, provided interactive and visual support to abstract mathematical content, bridging the gap between theoretical understanding and practical application. As reported by Ibáñez and Delgado-Kloos (2018), AR has the potential to enhance spatial and conceptual understanding, particularly in subjects like mathematics that involve geometric reasoning and visualization.

In Cycle I, students showed an initial increase in performance, although many were still adjusting to the use of AR tools. This observation is consistent with studies by Lin et al. (2020), which suggest that students often require an acclimatization period to effectively interact with emerging technologies in educational settings.

Subsequent improvements in Cycles II and III were a result of better integration of AR media into the RME-based learning design. This was accomplished through structured tasks, guided group discussions, and clear instructional scaffolding. According to Roschelle et al. (2017), learning technologies yield greater impact when embedded in well-designed pedagogical frameworks.

Increased engagement and motivation among students were also observed during the later cycles. Students were more willing to participate, ask questions, and collaborate with peers. A study by Cheng and Tsai (2019) found that AR learning environments significantly influence students' affective domain by reducing mathematics anxiety and promoting learning enjoyment.

Furthermore, classroom observations revealed that students began to demonstrate critical thinking and problem-solving skills. These skills are essential in 21st-century education and are among the core competencies emphasized by both RME and technology-enhanced learning (Voogt et al., 2015).

The improvement in students' learning outcomes was also supported by enhanced teacher performance. As teachers became more familiar with the RME framework and the AR technology, they were better able to facilitate learning. This finding echoes the

conclusion of Puspitasari et al. (2021), who argued that teacher competence in digital pedagogies is crucial for successful technology integration.

The qualitative data gathered from student interviews further reinforced the quantitative findings. Most students expressed enthusiasm and increased confidence in learning mathematics. According to a study by Rahmawati et al. (2022), positive emotional responses to learning experiences significantly contribute to long-term academic growth and conceptual retention.

Another important dimension is the collaborative aspect fostered by the learning design. Group-based problem-solving encouraged communication and the exchange of ideas among students. As Hwang and Lai (2017) highlighted, collaborative AR learning environments can promote peer learning and shared knowledge construction.

While the results were overwhelmingly positive, some challenges were noted, particularly in the initial implementation phase. These included technical issues with AR devices and the need for teacher support in managing the digital components of the lesson. These findings underscore the importance of providing professional development and technical infrastructure to ensure effective classroom use of educational technology (Alhumaidan et al., 2021).

Despite these challenges, the successful progression through the research cycles demonstrated that the integration of RME and AR is a promising strategy for addressing the longstanding issue of low mathematics achievement in elementary education. It shows that with proper planning and implementation, students can transition from being passive recipients to active participants in their own learning.

This study contributes to the growing body of evidence supporting the use of context-driven, technology-enhanced instructional models in mathematics education. The combined use of RME and AR offers a powerful alternative to traditional methods by fostering deep understanding, engagement, and positive learner attitudes.

CONCLUSION

The findings of this classroom action research demonstrate that the integration of the Realistic Mathematics Education (RME) approach with Augmented Reality (AR) media significantly enhances students' mathematics learning outcomes in elementary school. Through three cycles of intervention, there was a consistent and substantial improvement in both student test scores and classroom engagement. The contextual nature of RME helped students relate mathematical concepts to real-life situations, while the interactive features of AR media facilitated deeper conceptual understanding and increased motivation. The study confirms that this combined approach effectively addresses students' learning difficulties and fosters a more engaging, meaningful, and student-centered mathematics learning environment. Therefore, the RME approach assisted by AR media can serve as a valuable instructional strategy for improving mathematics education in primary schools.

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