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Enhancing Multiplication Skills Through Game-Based Learning and Realistic Mathematics Education: A Study in Primary School Mathematics

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Abstract: *In today's education, engaging students in mathematics while enhancing their skills is crucial. Mathematics is vital for critical thinking and problem-solving. Integrating game-based learning into the curriculum is a promising method to engage students dynamically and deepen their understanding. The traditional methods of teaching mathematics often struggle to engage learners and may not adequately address their diverse learning needs. There is a pressing need to explore innovative approaches that not only make mathematics enjoyable but also comprehensible for primary school students. This action research investigates the learning strategies of integrating game-based learning and Realistic Mathematics Education (RME) principles into mathematics lessons to enhance multiplication skills among fourth-grade students. Utilizing the Kemmis and McTaggart model, the research process involves a cyclical approach of planning, acting, observing, and reflecting. Through the implementation of various multiplication games and activities, the study assesses the impact of game-based learning on student engagement and performance. Findings indicate a significant improvement in multiplication skills among students exposed to game-based learning compared to those using traditional methods. Based on the results, suggestions for integrating game-based learning and RME principles into primary school mathematics learning are proposed. The study concludes that game-based learning and RME are promising approaches to fostering a positive learning environment and enhancing mathematical skills in primary school students.*

Keywords: Realistic Mathematics Education, game-based learning, multiplication skills, primary school

1. Introduction

The flaws of mathematics education in primary school have been already highlighted in multiple studies: Students struggle to understand mathematics, students struggle with creating and solving a mathematical model based on a contextual (or story) problem and finally, the teaching approach makes mathematics more complex to learn and grasp. Students have also been frightened of mathematics (Muhi, 2015). When discussing school learning issues, individuals believe that mathematics is the most difficult subject for children to learn. Common mistakes involving children with learning problems in mathematics include insufficient understanding of symbols, place values, and calculations (Chan & Scalise, 2022). Multiplication is a tricky area for children, especially third-grade children at the beginning of

the curriculum and teachers employ several strategies to support students in understanding multiplication (Sufa & Setiawan, 2018).

Considering the facts above, a significant question emerged: what is the alternative that we should implement to improve traditional teaching? After researching relevant literature studies, Realistic Mathematics Education (RME) along with game-based learning was chosen as the strategy that would hit for the paradigm of mathematics education in primary school. One of the most detailed and documented accounts of such a problem-based approach to mathematics education can be found in RME approaches to school mathematics. As initially developed in the Netherlands, this RME has been employed through a cooperative initiative, Mathematics in Context (MiC) in some schools in the USA. Thus, RME is not just a new way of teaching mathematics but also a new way of thinking about the goals and practices of school mathematics (Sembiring et al., 2008).

In the digital era, teaching mathematics through games is one of the most preferred methods in mathematics education today, just as it was in the past (Erşen & Ergül, 2022). Game-based learning (GBL) has emerged as a significant pedagogical approach in contemporary education, especially in mathematics (Erşen & Ergül, 2022). Traditional methods of teaching multiplication lack the ability to engage students, leading to gaps in foundational skills. However, integrating games into the learning process offers a compelling alternative by making mathematical concepts more accessible and enjoyable. Research has consistently shown that GBL not only enhances cognitive skills but also increases student motivation and engagement in mathematics learning (Pehlivan & Arabacıoğlu, 2023; Galiç & Yıldız, 2023; Kokandy, 2021). For example, studies have demonstrated the effectiveness of digital games in improving mathematical skills among primary school students, highlighting the potential of GBL as an innovative teaching strategy.

This blend of methods is effective because students can visualize and internalize what multiplication is as they apply it to problems that happen in life. Although GBL and RME have both been shown to improve mathematical learning, little is known about how these approaches can be integrated to achieve optimal learning outcomes in multiplication. For example, additional studies are warranted to investigate the distinct impacts of implementing GBL in conjunction with RME on various groups of learners and the lasting influence on comprehension of mathematical concepts and memory recall. In this study, we investigated the use of game-based learning to improve multiplication skills in primary school students with RME. We aimed to identify feasible instances of game-based pedagogical approaches within a mathematics context.

2. Research Focus

Regarding the subject of learning problems, which can be seen as hurdles with potential ramifications for both the individual and their environment, this problem is significant in its regard (Syafitri et al., 2021). If these obstacles persist as they have been, students will encounter educational setbacks and develop a feeling of inadequacy in their academic and social development. With that, we took the initiative to address these challenges and create a supportive learning environment for all students through reflection and short interviews with my students. The following is an extract from our observation and an interview in a primary school that illustrates a common way of mathematics teaching in the classroom.

> *One such observed mathematics lesson was in a primary school where students were taught to multiply two-digit numbers by two-digit numbers. The teacher started by telling students to listen closely, warning them that their comprehension of the lesson would depend on how carefully they listened. The teacher wrote out a problem on the whiteboard and solved it independently, talking through the steps she was writing. At times, the teacher called on the whole class for answers, with the students answering in unison. It praised correct answers and provided no feedback on wrong answers. The teacher asked if the students understood what she had just done, to which some said yes in unison, while others sat in silence. The teacher added another example using this same process to reinforce the concept. Then the students were sent to their textbooks to work on the same types of problems on their own. During this activity, we could tell that the students were having difficulty understanding the concept. This led to a short interview with a student to explore her understanding in more depth. While the student performed the calculation as instructed, she was not able to explain why she multiplied in which order, or where digits went in the solution. When asked about these processes, the student stated that she learned the teacher's method by rote and did not understand why it produced correct answers.*

Based on the observation and the brief interview, we concluded that this top-down, '*conventional*' teaching approach to school mathematics had a negative impact not only on students' perceptions of mathematics but also on their performance in assessments. It was frequently asserted that many students had developed *'a mathematics phobia'*, and others believed that their mathematical fear was to blame for their poor performance. As a result, we need to implement some instructional strategies that are appropriate for students' learning needs in this digital age.

3. Literature Review

The study was based on constructivist learning theories, which encourage active participation and meaningful learning experiences. This study combined the principles of game-based learning and Realistic Mathematics Education (RME) so that students can understand the concepts of multiplication more easily. Game-based learning was also used to boost the interest of students and make a positive process of learning while RME ensures that the topic of multiplication could be taught through a real-life context that is meaningful and relevant to student life. This literature suggests that applying realistic problem-solving scenarios in conjunction with interactive learning tools helps achieve effective learning interventions. In this study, by mixing these approaches we planned to create new insights into teaching to Year Four students, for them to develop a real understanding of multiplication through meaningful and enjoyable experiences.

3.1 Constructivism Theory

When technology is applied in a constructivist way to teach multiplication, it becomes a powerful tool. Instead of just memorizing the 3 x 4 = 12, we should think about the math classroom of the future where learners are immersed in gamified learning apps or virtual manipulatives and can practice multiple real-world situations to explore multiplication. Constructivism is a theory of learning in which students gain a deeper understanding through active engagement with complex situations. This is a unique integration of the theories of learning and the method of teaching which, used as a foundation, guides a teacher to build a constructive, game-based, and realistic mathematics classroom. Well-integrated technology

can improve the process of students constructing their learning on multiplication with other peers and teachers and vice versa. Constructivism, which is the learning theory in which knowledge is actively constructed by the learner rather than passively received, was used in this study. According to Piaget, students construct their understanding of the world based on what they experience and reflect on it (Rabillas et al., 2023). Constructivism, like choice theory, accommodates a classroom where students explore, ask questions, and solve problems to make learning an active and personal process. It is the teacher's role to guide this process by providing adequate tools, challenges, and guidance, allowing students to construct their knowledge and develop deeper conceptual understanding.

3.2 Game-Based Learning

Game-based learning (GBL) in mathematics has gained substantial attention due to its potential to enhance student engagement, motivation, and learning outcomes. Research indicates that integrating games into mathematics education can significantly improve students' mathematical confidence and performance, particularly when tailored to their ability levels (Himmawan & Juandi, 2023). Additionally, GBL fosters a positive attitude toward learning mathematical concepts, as students find the interactive and competitive elements of games enjoyable (Hwa, 2018). Both digital and non-digital games are effective, with primary school teachers demonstrating a preference for non-digital games due to their simplicity and accessibility (Russo et al., 2024). However, digital games offer opportunities for personalized learning experiences that can be adapted to individual student needs, thereby supporting differentiated instruction (Nguyen Ngoc Dan et al., 2024).

Studies showed that game-based learning helps students in learning multiplication. For example, the study by Mohamed Ali@Md Hani et al. (2021) showed that the development of Forest Multiplication Game-Based Learning Apps can assist students overcome mathematical topic learning challenges and improve their learning experience. Besides, the study by Arciosa (2021) showed that using the mechanical GBL as a major instructional aid in teaching basic mathematics got very satisfactory ($x = 3.50$) respondents' responses in the actual classroom demonstration. The use of game-based instructional strategies in mathematics education provides a dynamic and interactive approach that can cater to diverse learning styles and promote a deeper understanding of mathematical concepts.

3.3 Realistic Mathematics Education (RME)

Realistic Mathematics Education (RME) is a pedagogical approach that emphasizes the use of real-world contexts and problems to make mathematical concepts more meaningful and accessible to students. Originating from the Netherlands, RME encourages students to develop their strategies and solutions by engaging with realistic scenarios, thereby fostering a deeper understanding of mathematical principles (Makonye, 2014; Barnes, 2005). The instructional strategies within RME include the use of models and representations that students can relate to, which helps bridge the gap between informal and formal mathematical knowledge (Makonye, 2014). Additionally, RME has been shown to improve mathematical learning outcomes by promoting active student involvement and allowing students to explore mathematical concepts through guided reinvention and reflection (Fredriksen, 2021).

Studies showed that students gained a conceptual understanding of mathematics concepts through Realistic Mathematics Education. For example, Setiadi (2020) shared about the instructional strategies were taken in implementing RME: (1) analyzing in detail students' difficulties in vertical multiplication and division, (2) providing contexts of mathematical problems that can stimulate students to think mathematically, (3) holding a class mathematics

congress, and (4) administering a test to assess students' achievement. The use of RME has helped fifth-grade students enhance their multiplication and division skills (Setiadi, 2020). Besides, Yorulmaz and Cihangir Doğan (2022) conducted a study that found that operational, conceptual, and problem situations were the main sources of mistakes among fourth-grade students. Implementing Realistic Mathematics Education (RME) activities led to a decrease in mistakes, indicating that RME is an effective method for reducing mistakes in primary school. Overall, RME provides a robust framework for teaching mathematics in a way that connects mathematical theories with everyday experiences, making learning more engaging and effective.

4. Research Objectives and Research Questions

This study explores how the principles of Realistic Mathematics Education (RME) can be integrated into game-based learning to enhance students' understanding of two-digit multiplication. By incorporating RME, which emphasizes contextual and real-world problem-solving, the study aims to create engaging and meaningful learning experiences that help students grasp complex mathematical concepts more effectively. The research will focus on identifying specific strategies for embedding RME into game-based activities, examining how these approaches can deepen students' conceptual understanding of multiplication, and evaluating the overall impact on their learning outcomes.

5. Research Methodology

5.1 Research Design

An action research approach in this study was driven by its focus on investigating real-world school or classroom contexts to better understand and improve the effectiveness of instructional practices (Johnson, 2012). This study followed the model outlined by Kemmis and McTaggart (1988), which involves four key stages: Observation, Reflection, Planning, and Implementation of actions (see Figure 1). The research was conducted within a single cycle, during which students exhibited noticeable progress in response to the implemented intervention.

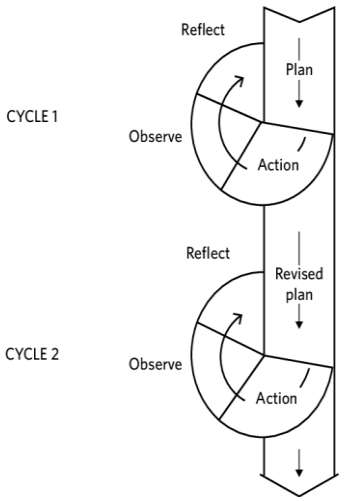

Figure 1: Kemmis and McTaggart model (1988, cited in Burns, 2010)

5.2 Research Sample

This action research project engaged five Year Four students enrolled in a Chinese national-type primary school. Purposive sampling, a non-probability sampling method, was employed due to the practical constraints of the school setting and the researcher's accessibility (Creswell,

2014). Participants were chosen based on observations, previous UASA test scores, and preliminary investigations. These selected students participated in an 8-week intervention as part of the study.

5.3 Research Instrument

To address the research questions, this study used pre-tests, post-tests, and an adapted interview. The data validity test was carried out, namely the data credibility test by triangulation. Pre-tests and post-tests were administered to participants before and after the intervention respectively. Statistical analysis, conducted using SPSS, involved comparing means and standard deviations to ascertain any significant differences in scores. A few sessions of interviews were conducted with participants to identify the strategies for implementing game-based learning and RME. The qualitative data was then translated and transcribed to answer the research objective and question.

5.4 Theoretical Framework

The constructivist framework of this study was rooted in the theories of Piaget and Vygotsky to emphasize that learners actively construct knowledge through experiences and interactions. In this study, constructivist principles were integral to both the design and implementation of the interventions aimed at enhancing multiplication skills among Year Four students. Learning is most effective when students can relate new information to their existing knowledge base through meaningful contexts. By situating multiplication within practical applications, such as managing a virtual shop, students were encouraged to build upon their prior experiences, facilitating deeper understanding and retention.

RME focuses on connecting mathematical concepts to real-life situations, enabling students to perceive the relevance and applicability of what they learn. In this study, RME principles were applied by designing tasks that mirrored everyday activities, such as shopping or resource management, to teach multiplication. This approach encourages students to construct their understanding by solving problems that make sense within their daily experiences. The use of games in education is a constructivist strategy that promotes active engagement and motivation. In this study, educational games were employed to present multiplication challenges in an interactive and enjoyable manner. This method supports the constructivist idea that learners are more likely to internalize concepts when they are actively involved in the learning process and can experiment within a safe, game-based environment.

Within the constructivist framework, the teacher acts as a facilitator rather than a mere transmitter of knowledge. In this study, the teacher guided students through the learning activities, provided scaffolding when necessary, and encouraged collaborative problem-solving. This facilitative role is crucial in helping students navigate their learning paths, ask questions, and develop critical thinking skills, all of which are central to constructivist pedagogy.

5.5 Intervention Design

The intervention plan in this action research was planned and implemented based on Kemmis and McTaggart's (1988) model, game-based learning, and RME (See. Figure 2). To effectively integrate Realistic Mathematics Education (RME) into game-based learning for two-digit multiplication, the intervention begins by identifying real-world contexts where multiplication is naturally used, such as calculating the total cost of multiple items or determining areas in construction. For example, students might calculate the cost of 12 items priced at RM 15 each, connecting the concept to everyday life. Next, these contexts are transformed into

contextualized problem scenarios within the game, such as managing a virtual shop where students apply two-digit multiplication to complete transactions. The game mechanics are then integrated, using levels, rewards, and feedback loops to engage and motivate students, where correct answers unlock new levels or earn points. The game encourages exploration, allowing students to develop and test different strategies, like using the distributive property to solve multiplication problems. After gameplay, group discussions are facilitated to reflect on the strategies used, helping students articulate their understanding. Immediate feedback is provided within the game to reinforce correct methods and correct errors, with prompts or mini lessons when necessary. The learning is then assessed through reflective exercises and application tasks that extend beyond the game, ensuring students have internalized the multiplication concepts. Finally, the game and activities are iterated based on student feedback and observed challenges, refining the learning process to maintain its effectiveness and engagement.

Figure 2: The intervention plan

6. Findings and Discussions

6.1 Findings and Discussion on Pretest and Posttest

The research study used pre-tests and post-tests administered before and after the intervention was conducted. Table 1 illustrates the scores obtained by the participants before and following the intervention.

Table 1: The Improvements in Participants

Participant	Pre-test (%)	Post-test (%)	Difference (%)
Student A	30	80	+50
Student B	20	80	+60
Student C	30	90	+60
Student D	30	100	+70
Student E	40	90	+50

Table 1 shows pretest and post-test scores and reveals a clear improvement in student learning following exposure to the intervention plan. This is evident when we look at both the average scores and individual student progress. The average pretest score was 30, while the average post-test score was 80. This substantial gain of 50 points suggests that the intervention plan with game-based learning and RME was successful in helping students grasp the concept of multiplication. Student A, for example, demonstrated a significant improvement from 30 on

the pretest to 80 on the post-test, which is a 50-point increase. Likewise, Students B, C, and D all showed similar gains following the intervention plan. Even Student E, who had the smallest improvement at 30 points, still exhibited a positive increase in knowledge. Therefore, the pretest-post-test results provide strong evidence that game-based learning and RME led to a significant improvement in student learning outcomes (Jones et al., 2021; Sumeracki et al., 2024).

6.2 Findings and Discussion on Interview Data

The interview transcription reveals several emerging themes that highlight the effectiveness of integrating Game-Based Learning (GBL) and Realistic Mathematics Education (RME) in teaching two-digit multiplication. One prominent theme is the increased engagement and motivation among students. The use of games transformed multiplication problems into real-life challenges, making the learning process more enjoyable and memorable. Students appreciated the contextual relevance of the tasks, such as calculating prices in a shop management game, which allowed them to see the practical applications of multiplication beyond the classroom. Another theme is the enhancement of understanding through the strategic breakdown of complex problems into smaller, manageable steps. The immediate feedback provided in the game environment was also crucial, as it helped students quickly identify and correct their mistakes, reinforcing their learning. Additionally, collaborative learning emerged as a significant factor, with students benefiting from group discussions where they shared and compared problem-solving strategies. This peer interaction not only deepened their comprehension but also introduced them to diverse approaches to the same mathematical challenges. The transcription below shows the positive comments from two participants in this study.

Teacher: How do you feel about using this way to learn two-digit multiplication?

Student A: I enjoyed it! The games made the multiplication problems feel like real-life challenges. It wasn't just about getting the right answer but also understanding why we were doing multiplication in the first place. It was fun and made it easier to remember.

Teacher: Can you explain how it helped you in learning multiplication?

Student A: The strategies, like breaking down the multiplication into smaller steps, really helped. For example, when we played the shop management game, we had to calculate the total prices for items. It was like managing a real store, so I felt more connected to what I was learning. The hints and feedback in the game also helped me correct my mistakes right away.

Student B: I agree! The game made it interesting to figure out the answers, and the real-life scenarios showed me how I can use multiplication outside of school. Discussing strategies with my classmates after the game helped me see different ways to solve the problems. It was cool to hear how everyone approached the challenges.

Teacher: So, you found this way effective?

Student B: Definitely. It was much more engaging than just doing worksheets, and I think I learned better because it made sense to me in a real-world way.

In summary, the integration of GBL and RME not only made learning more relevant and engaging but also supported the development of critical thinking and problem-solving skills in a real-world context.

7. Summary, Reflection, and Recommendations for Follow-Up Actions

The study explored how the principles of Realistic Mathematics Education (RME) can be integrated into game-based learning to enhance students' understanding of two-digit multiplication. The findings indicate that these approaches enhanced students' engagement, motivation, and understanding of multiplication concepts. The contextual relevance of RME, combined with the interactive nature of GBL, facilitated deeper comprehension and retention of mathematical skills (Fathul Jannah et al., 2023). Students reported that these methods made learning more enjoyable and relevant to real-life situations, leading to improved problem-solving abilities (Yorulmaz & Cihangir Doğan, 2022).

The positive feedback from participants highlights the importance of integrating interactive and context-based learning strategies in mathematics education. The alignment of learning activities with real-world applications not only increases student motivation but also supports the development of critical thinking skills (Setiadi, 2020). The immediate feedback provided in game-based environments allowed students to self-correct and learn from their mistakes, further enhancing their understanding. However, this study also highlighted the need for ongoing teacher training to effectively implement these innovative teaching methods (Palupi & Khabibah, 2018). The findings of this study suggest practical implications for teachers and policymakers and highlight the need for a paradigm shift in teaching practices, moving away from rote learning toward contextualized and interactive methodologies.

The study demonstrates that integrating Realistic Mathematics Education (RME) and Game-Based Learning (GBL) significantly enhances student engagement by embedding mathematical concepts into real-world contexts. According to Fredriksen (2021), contextual learning aligns students' mathematical understanding with everyday scenarios, making lessons more relatable and reducing math anxiety. Educators can leverage these strategies to design lessons that maintain student interest and facilitate long-term retention of skills. Furthermore, game-based environments offer opportunities for personalized learning, where students can progress at their own pace and receive immediate feedback tailored to their responses. Nguyen Ngoc Dan et al. (2024) found that adaptive game mechanics effectively address diverse learning styles and abilities, allowing for differentiated instruction. Teachers can adopt these tools to provide targeted interventions, improving outcomes for all learners.

The study highlights how group discussions and peer collaboration in the context of GBL and RME improve critical thinking and problem-solving skills. As Russo et al. (2024) observed, collaborative learning not only deepens conceptual understanding but also encourages students to explore diverse approaches to problem-solving. Educators can foster a collaborative environment by incorporating group tasks into their lesson plans. Therefore, teachers should adopt GBL and RME strategies to create a more engaging mathematics curriculum. The accessible and inclusive nature of GBL and RME ensures that students from diverse backgrounds can engage meaningfully with mathematical concepts. Yorulmaz and Doğan (2022) note that contextualized learning reduces performance gaps by addressing the unique needs of underrepresented or struggling students. Equitable access can be promoted by ensuring that digital tools and learning resources are available across all schools.

For policymakers, the findings suggest that GBL and RME can be integrated into national curricula to promote active, inquiry-based learning. Studies by Hwa (2018) emphasize that such approaches align with 21st-century education goals, particularly in fostering critical thinking and creativity. To make it a success, policymakers should develop guidelines and provide resources for educators to implement these innovative methods effectively. Implementing GBL and RME requires specific pedagogical skills, such as designing contextual problems and managing game-based interventions. Palupi and Khabibah (2018) recommended professional development programs focused on equipping teachers with these skills. Hence, policymakers should allocate resources for training workshops and continuous support systems to build teacher capacity in using these methods.

8. Conclusion

Given the weaknesses identified in traditional mathematics teaching—such as difficulties in comprehending mathematical concepts and a general aversion to the subject—the integration of Game-Based Learning (GBL) with Realistic Mathematics Education (RME) offers a promising alternative. RME emphasizes contextualizing mathematics through real-life problems, which helps students relate to and understand mathematical concepts better. Originating in the Netherlands, RME focuses on problem-solving within realistic contexts, making learning more meaningful and effective for students. GBL incorporates interactive games into the learning process, which has been shown to enhance student engagement and motivation. By making mathematics more enjoyable and interactive, GBL helps students overcome learning barriers and improves their performance, particularly in learning multiplication through personalized and engaging experiences. Combining RME with GBL involves using game scenarios that reflect real-world contexts, such as virtual shopping or construction tasks, to teach multiplication. This approach not only makes learning more engaging but also helps students internalize mathematical concepts through practical application. The study found that this combined approach led to significant improvements in students' understanding and performance in multiplication.

However, there are limitations, and it is important to address them in this study. This study is limited to the influence of the teacher's role, the sample of the participants, and the Hawthorne effect where participants may alter their behavior simply because they are aware they are part of a study. For future research, we suggest that broader applications of RME and GBL to different educational contexts should be explored. Future research may investigate how these methods can be applied to diverse subjects. Researchers may conduct research with larger and more diverse student populations to validate findings and assess scalability. In summary, integrating RME and GBL offers a robust framework for addressing the challenges faced in traditional mathematics teaching, providing students with a deeper understanding of multiplication and a more positive attitude toward mathematics.

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