JPPIPA 11(7) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Mathematic Games as an Educational Technology Strategy to Improve Motivation and Learning Outcomes of Elementary School Students

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Received: March 14, 2025
Revised: June 21, 2025
Accepted: July 25, 2025
Published: July 31, 2025

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DOI: 10.29303/jppipa.v11i7.12253

Abstract: This study investigated the effect of Mathematics Games and learning motivation on the mathematics achievement of fifth-grade students at SDN 03 Koto Kaciak. Using a quantitative approach with a 2×2 factorial quasi-experimental design, students were assigned to experimental and control groups. Data were collected through pre- and post-tests and a learning motivation questionnaire. Two-way ANOVA was used for analysis. The results showed that the Mathematics Games method did not significantly affect learning outcomes ($p > 0.05$), although the experimental group demonstrated slightly higher mean scores than the control group. In contrast, learning motivation significantly influenced students' mathematics achievement ($p < 0.05$), with high-motivation students outperforming their peers. No significant interaction was found between teaching method and motivation level. These findings suggest that while the Mathematics Games method did not produce statistically significant gains, learning motivation remains a key factor in academic success. The study's contribution lies in its contextual application of Mathematics Games as an instructional strategy in a rural elementary school setting, highlighting the importance of implementation quality and learner characteristics. Further research with longer treatment duration and larger samples is recommended to assess long-term effects and refine the integration of educational games in elementary mathematics instruction.

Keywords: Elementary school; Learning outcomes; Mathematics games; Motivation; Technology Education

Introduction

Advances in educational technology have brought major changes in the world of learning, including at the elementary school level (Sucipto, 2024). Today's educational technology is not only limited to the use of digital devices, but also includes a systematic approach that aims to create a more effective, enjoyable, and appropriate learning experience in accordance with the needs of students' psychological development (Habibi, 2023; Marwati et al., 2024). However, the reality in the field still shows that the learning process, especially in mathematics subjects, is generally still running conventionally and has not made optimal use of technology-based approaches.

This condition is strengthened by the findings at SDN 03 Koto Kaciak, where mathematics learning is still dominated by lecture methods and the use of Student Worksheets (LKS), which are general and have not been adjusted to local characteristics and concrete needs of students. As a result, students become less motivated and inactive in the learning process. The data also shows that only 45% of students manage to achieve the

How to Cite:
Hartati, S. M., Rahmi, U., Jasrial, & Ridwan. (2025). Mathematic Games as an Educational Technology Strategy to Improve Motivation and Learning Outcomes of Elementary School Students. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 762–769. https://doi.org/10.29303/jppipa.v11i7.12253

Minimum Completeness Criteria (KKM), a figure that is far from the classical completeness standard of 80%. In fact, as a basic subject, mathematics plays an important role in forming logical and systematic thinking skills. Therefore, an innovative approach is needed that can bridge abstract material with students' real-life experiences in a contextual and enjoyable way.

Responding to this need, one potential solution is the use of mathematics games, which is a game-based learning model developed with an educational approach (Ananta et al., 2024; Dari et al., 2022; Safitri et al., 2023). These types of games, both traditional and digital, play a role in creating a learning atmosphere that is more interactive, engaging, and responsive to different learning styles (Afifa & Astuti, 2024; Iskandar et al., 2023). In addition to increasing motivation, the use of mathematics games also encourages students to participate more actively in the learning process. This approach is in line with educational technology principles that emphasize a flexible, fun, and student-centered learning strategy (Hala & Xhomara, 2024).

Various studies have corroborated the effectiveness of the use of games in mathematics learning. Rakasiwi & Muhtadi (2021) showed that the use of geometry-based games was able to increase learning motivation by up to 84.4% and students' average scores significantly. Debrenti (2024) also found that non-digital games have a greater impact on the understanding and motivation of elementary school students than digital games. In addition, the study of Qolbi et al. (2019) proves that language context-based games are able to improve engagement and mathematical verbal skills. However, most of these studies only position games as an auxiliary medium or variation of learning methods, rather than as part of an overarching educational technology strategy.

By paying attention to these findings, an important research gap emerges to be answered, namely the absence of a study that explicitly positions mathematics games as a learning strategy based on educational technology that integrates pedagogical, psychological, and contextual aspects. In addition, very few studies have directly examined the interaction between students' learning motivation levels and the use of mathematics games methods on mathematics learning outcomes. This means that research is still needed that not only assesses the effectiveness of the method, but also looks at how it works alongside the student's internal factors to produce optimal learning.

In this context, the novelty of this research lies in its approach that places mathematics games not only as an auxiliary medium, but as an educational technology strategy that is systematically designed. This approach combines instructional design, learning motivation, and characteristics of elementary students in one unified framework. Thus, this research is expected to contribute to the development of a learning model that is more fun, meaningful, and adaptive to the needs of 21st-century students (Anggraini & Hudaidah, 2021).

Based on the background and research gaps that have been identified, this article aims to analyze the influence of the use of mathematics games as an educational technology strategy on the motivation and learning outcomes of mathematics in elementary school students. In addition, this article also aims to explore the interaction between learning methods and students' motivation levels in creating an effective, adaptive learning process that supports comprehensive mastery of mathematical concepts.

Method

This study employed a quantitative approach using a quasi-experimental factorial design (2×2) (Sugiyono, 2013), aimed at examining the effects of the Mathematics Games learning method and students' learning motivation on mathematics learning outcomes in elementary school. The quasi-experiment design was selected due to the absence of full randomization, which is common in educational settings. The factorial structure allowed the researchers to investigate both the main effects and interaction effects of two independent variables: learning method (Mathematics Games vs. conventional) and learning motivation (high vs. low). The dependent variable was students' mathematics learning outcomes.

The research was conducted at SDN 03 Koto Kaciak, Tanjung Raya District, Agam Regency, involving all fifth-grade students during the 2024/2025 academic year. Because the population was small and all students were included in the intervention, the study used a census approach. The entire group was then divided into two classes: an experimental group receiving instruction using the Mathematics Games method, and a control group using conventional teaching methods.

Two main instruments were used: a mathematics learning outcome test, consisting of multiple-choice items covering integer and fraction operations based on the current curriculum, and a learning motivation questionnaire based on a Likert scale with intrinsic and extrinsic indicators. Both instruments were tested for content validity through expert judgment (involving three subject-matter experts), and for reliability through a small-scale trial involving 30 students from another school. The mathematics test showed a Cronbach's Alpha of 0.81, and the motivation questionnaire achieved an Alpha of 0.84, indicating high internal consistency. In addition, observation sheets were used to document classroom activities, and relevant documents were collected as supplementary data.

The study follows a structured procedure as shown in Figure 1.

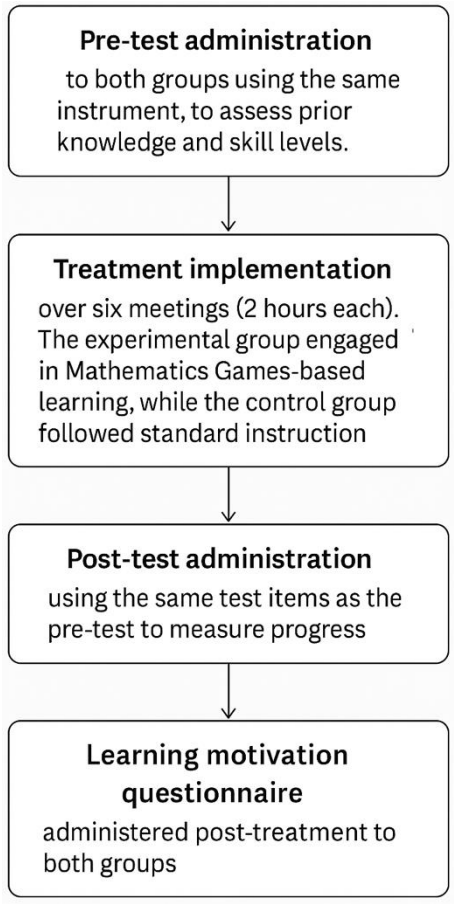

Figure 1. Research procedure

The data from the study was analyzed using two-way variant analysis (Two-Way ANOVA). This technique is used to test the main influence of learning methods, the influence of learning motivation, and the interaction between the two on mathematics learning outcomes. Before the analysis, the data was first tested for normality and homogeneity assumptions to ensure the feasibility of using ANOVA. The results of this analysis are the basis for drawing conclusions about the effectiveness of Mathematics Games as an educational technology strategy in improving the motivation and learning outcomes of elementary school students.

Result and Discussion

After all treatment stages were completed, data obtained from the test results and motivation questionnaire were analyzed to determine the effect of the Mathematics Games method and the level of learning motivation on students' mathematics learning outcomes. The analysis was conducted using a two-way ANOVA test, which aims to examine the effect of each independent variable separately and its interaction with the dependent variable. This analysis is important to answer the focus of the research, namely whether the Mathematics Games strategy as part of an educational technology approach can make a significant contribution to improving the motivation and mathematics learning outcomes of elementary school students.

Table 1. Two-way ANOVA

Source	Sum of Squares	Df	Mean Square	F	Sig.
Method (A)	338.017	1	338.017	1.456	0.238
Motivation (B)	1428.017	1	1428.017	6.153	0.020*
A × B	12.017	1	12.017	0.052	0.821
Error	6036.933	26	232.190		
Total	215625.000	30			

Note: * Significant at α = 0.05

Based on the two-way ANOVA analysis, several main findings were obtained, including: The influence of the mathematics games method (A), the influence of learning motivation (B), and interaction between mathematics games method and learning motivation (AxB).

The Influence of the Mathematics Games Method (A)

The F value = 1.456 with significance (Sig.) = 0.238 (> 0.05), shows that there is no significant influence of the learning method on the mathematics learning outcomes of fifth grade students at SDN 03 Koto Kaciak.

The Influence of Learning Motivation (B)

The F value = 6.153 with significance (Sig.) = 0.020 (< 0.05), which means that student learning motivation has a significant influence on the mathematics learning outcomes of fifth grade students of SDN 03 Koto Kaciak. Students with high motivation tend to get better grades than students with low motivation. This confirms that internal factors such as motivation play an important role in academic achievement.

Interaction between Mathematics Games Method and Learning Motivation (AxB)

The F value = 0.052 with a significance (Sig.) of 0.821 (> 0.05), this shows that there is no significant interaction between the Mathematics Games method and students' learning motivation on the mathematics learning outcomes of fifth grade students at SDN 03 Koto Kaciak.

The results of the study indicate that the use of the Mathematics Games method did not have a statistically significant effect on improving mathematics learning outcomes. This finding contradicts initial expectations that predicted the Mathematics Games method would

significantly improve learning outcomes. Several factors contributed to the insignificant effect of the Mathematics Games method, including: implementation factors, research time factor, and Student Characteristic Factors.

Implementation Factors

The implementation of the Mathematics Games method may not have been optimal in this study. Using games in learning requires thorough preparation, a deep understanding of the teacher's educational game concept, and sufficient time for students to adapt to the new method.

As Putra & Marta (2024) demonstrated, increased student motivation through game-based learning methods was only achieved after two cycles of action. This indicates that implementing game-based learning methods requires time, student adaptation, and teacher readiness, so their effectiveness is not immediately apparent in the short term.

Salazar & Gumanoy (2025) also provide a strong theoretical basis that innovative learning strategies, such as differentiated and game-based approaches, require careful planning and gradual implementation to achieve optimal results. These strategies cannot immediately produce significant changes in one or two sessions, because student engagement in new learning models is highly dependent on their prior experiences, cognitive readiness, and learning styles.

Furthermore, Gök & Karamete (2025) noted that innovative learning designs such as games or mathematical modeling require active teacher involvement to gradually adapt activities to students' abilities and needs. Teachers are required to have a deep understanding of instructional design principles for effective implementation of learning media.

Thus, the lack of significant impact of Mathematics Games in this study can be explained by the transition phase, which has not yet reached its peak effectiveness. Teachers and students may still be adapting, and the media has not yet been fully integrated into a consistent learning strategy. These findings reinforce the point that in game-based educational technology approaches, implementation time, teacher training, and student engagement are important variables influencing long-term effectiveness.

Research Time Factor

The relatively short duration of the study may not have been sufficient to demonstrate the significant impact of the Mathematics Games method. Changes in learning outcomes resulting from new learning methods typically take longer to become visible.

Based on the constructivist learning theory proposed by Piaget (1952), elementary school students are in the concrete operational stage, where understanding of mathematical concepts develops through direct experience, repetition, and gradual processing. Meanwhile, Vygotsky (1981) stated that effective learning occurs in the Zone of Proximal Development (ZPD), which requires guidance until students are able to master the material independently.

The limited duration of the study, which consisted of only a few sessions, could hamper the internalization process, as highlighted by Kiili et al. (2018), who emphasized that indicators of learning through games often emerge after students have achieved deep engagement in the game, which cannot be achieved in a short time. Furthermore, Tokac et al. (2019) showed that intervention duration is an important moderator in the success of game-based learning: programs with longer durations showed greater effects on mathematics learning outcomes than short-term interventions.

Furthermore, Hussein et al. (2022) also concluded that the effectiveness of games depends heavily on consistent implementation and sufficient time for exploration and reflection, especially at the elementary level. In this study, game-based approaches tend to yield maximum results when integrated comprehensively into the curriculum, rather than simply as short-term interventions. Finally, the findings of Moon et al. (2025) also highlight the importance of long-term planning in integrating game-based learning so that teachers can understand student characteristics and develop appropriate mentoring strategies.

The limited duration of this study is a key factor explaining why Mathematics Games have not shown a significant impact on learning outcomes. Game-based learning requires time to allow for meaningful engagement, optimal mentoring, and in-depth internalization of concepts. Therefore, to achieve optimal results, the implementation of Mathematics Games should be gradual, continuous, and over a sufficiently long period.

Student Characteristic Factors

The characteristics of fifth-grade elementary school students who are still in the cognitive development stage indicate that the implementation of game-based learning methods needs to be adjusted structurally and gradually, because not all students have the same readiness to learn through this approach. This is reinforced by Ding & Yu (2024), who showed that the effectiveness of game-based learning is influenced by the type of pedagogy used as well as the duration and intensity of student involvement in playing games, especially at the elementary education level. Students who are not yet accustomed to this approach need more time and systematic direction to understand concepts through games.

Furthermore, Partovi & Razavi (2019) study emphasized that game-based learning can significantly improve motivation and learning outcomes, but the success of its implementation is highly dependent on student readiness, the depth of game design, and integration with learning objectives.

Meanwhile, the results of a systematic review by Guan et al. (2024) and Plass et al. (2015), showed that at the elementary school level, the implementation of game-based learning is most effective when it is adapted to the level of cognitive, social, and emotional development of students, and is provided in a gradual and structured manner.

Thus, a game-based learning approach in fifth grade must be designed with student readiness variability in mind, while also facilitating ongoing scaffolding and guidance to truly serve as an effective learning strategy. Without the right structure and stages, games' potential to support learning can be suboptimal or even confusing for some students.

Meanwhile, the influence of learning motivation on mathematics learning achievement is very significant. This finding aligns with the motivational theory of Badateng (2020) and Pratiwi (2022), which emphasizes that students with high learning motivation tend to have greater persistence, interest, and better learning strategies, resulting in higher academic achievement. Motivated students are more actively involved in the learning process, have greater confidence in solving mathematics problems, and are less likely to give up when faced with difficulties.

This analysis is supported by several studies highlighting the role of motivation in learning. For example, research by Ndoa & Jumadi (2022) showed that interactive and structured learning can increase student motivation. Similarly, Erlitaviana & Tyas (2025) found that the appropriate use of visual media can increase learning motivation and impact academic outcomes.

Students with high motivation—both intrinsic and extrinsic—show consistently better academic achievement in mathematics than students with low motivation (Auliyah & Kusaeri, 2024; Lv et al., 2019; Moenikia & Zahed-Babelan, 2010). However, there are significant differences between students with low motivation. Some students are still able to achieve good results, indicating the presence of other factors such as family support, initial abilities, teacher strategies, or evaluation systems that encourage success without high motivation (García et al., 2016). This is supported by research by Harianja & Tampubolon (2025), which states that learning environment factors also play a role in shaping student motivation and learning outcomes.

Pedagogically, these results have important implications. First, teachers must be able to regularly identify students' motivation levels and design learning that is tailored to each student's motivational characteristics. Second, strategies used must consider different interventions for highly and low-motivated students. For students with low motivation but high potential, a more individualized approach and emotional support are essential. This aligns with the opinion of Sari & Paidi (2023), who demonstrated that inquiry-based learning models can foster motivation and learning success, especially in students with low motivation.

This confirms that learning motivation is not only a predictor of learning outcomes but also a crucial indicator in designing effective learning strategies. When high motivation is combined with appropriate learning strategies, such as game-based or inquiry-based media, learning outcomes can be optimized. Conversely, for students with low motivation, teachers need to provide personalized, contextual, and empowering learning stimuli to ensure they can still achieve optimal academic results.

The relationship between learning methods and student motivation is a major concern in education. This study shows that there is no significant interaction between the Mathematics Games learning method and learning motivation on mathematics learning outcomes. This suggests that the effectiveness of Mathematics Games is relatively neutral, both for students with high and low motivation. In other words, the success of using math games is not determined primarily by students' motivation levels, but rather by the quality of the learning design and its implementation in the classroom.

In line with Slavin (2012) view, which states that the effectiveness of a learning strategy is determined more by the quality of its design, integration with learning objectives, and implementation, rather than individual student characteristics such as motivation. Games that are not designed with strong pedagogical considerations in mind tend to fail to deliver maximum impact, even if students are highly motivated.

Student motivation is influenced by the extent to which the learning environment supports the needs for autonomy, competence, and social relatedness (Deci & Ryan, 1985). If these elements are not embedded in the design of a math game, students' intrinsic motivation will not grow, and the game's effects will not be optimal, even for students with strong learning motivation.

The implication of this research is that although learning motivation plays a crucial role in the learning process, the effectiveness of using Mathematics Games depends more on the integration of appropriately designed learning strategies. This means that the success of a game-based approach is determined not only by the level of student motivation, but also by how the games are implemented pedagogically. Therefore, the implementation of Mathematics Games needs to be

accompanied by strategies that can systematically increase learning motivation. These strategies include reinforcing learning objectives through explaining the tangible benefits of the material for students, as proposed by Locke & Latham (2002), providing rewards or positive feedback appropriate to learning outcomes, and utilizing the local context by integrating cultural and environmental elements into the games, as emphasized by Vygotsky (1981). With a combination of mature instructional design and relevant motivational interventions, the use of games in mathematics learning can provide more optimal results for student learning outcomes.

Conclusion

Learning motivation has a significant influence on elementary students' mathematics achievement. Learners with higher motivation levels consistently perform better and demonstrate greater academic stability compared to their peers. In contrast, the Mathematics Games method did not yield a statistically significant effect on learning outcomes, although a positive trend was observed, particularly among students with low motivation. The absence of a significant interaction between learning methods and motivation levels suggests that the impact of Mathematics Games is not dependent on students' initial motivation. Instead, its effectiveness is likely determined by the quality of classroom implementation and instructional design. This study is limited by its relatively short intervention period, small sample size, and the focus on a single school. Future research is encouraged to involve broader sample groups, extend the treatment duration, and further refine game-based learning strategies that are contextualized to primary education and aligned with the goals of mathematics instruction.

Acknowledgments
The researcher expresses sincere thanks to the supervisor for the valuable criticism and feedback provided during the preparation of this article. Sincere thanks to SD Negeri 03 Koto Kaciak, for their support and contribution to this research. The researcher is also very grateful to the advisors and examiners for their constructive input and suggestions.

Author Contributions
S.M.H. develops research concepts, designs methodologies, analyzes data, writes articles, and conducts research activities; U.R., J., and R. review and assess each stage of the article writing process and the implementation of the research.

Funding
This research uses private funds.

Conflicts of Interest
The authors declare no conflict of interest.

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