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The Effectiveness of a Challenge-Based Gamification Learning Model in Addressing Students' Difficulties in Memorizing Multiplication Facts at SDN 3 Plampang

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Abstract
This research was motivated by the low ability of elementary school *students to memorize multiplication, which affects their difficulties in understanding mathematics materials. Conventional learning methods cause students to be less motivated and less active in the learning process. This study aims to determine the implementation of the Challenge-Based Gamification Learning Model, analyze its effectiveness in improving multiplication memorization skills, and identify the supporting and inhibiting factors in its implementation among students at elemantary school 3 of Plampang. This research employed a mixed methods approach with an embedded mixed methods design. The research subjects consisted of 20 students in the experimental class and 21 students in the control class. Data were collected through pretest-posttest tests, observations, interviews, and documentation, then analyzed using statistical tests with the assistance of IBM SPSS 26 and qualitative data analysis. The results showed that the implementation of the Challenge-Based Gamification Learning Model was carried out through the stages of orientation, challenges, games, rewards, reflection, and evaluation. The average score of the experimental group increased from 69.25 to 83.00, while the control group increased from 55.71 to 69.29. The results of the paired sample t-test showed a significance value of 0.000 (<0.05), and the independent sample t-test obtained a t-value of 5.018 with a significance value of 0.000 (<0.05), indicating a significant improvement and difference in learning outcomes. The N-Gain test showed an increase of 47.19% in the experimental group and 31.53% in the control group. Based on the research findings, it can be concluded that the Challenge-Based Gamification Learning Model is effective in overcoming multiplication memorization difficulties among students at elemantary school 3 of Plampang. This model improves students' multiplication memorization skills, learning motivation, activeness, and engagement in mathematics learning. The supporting factors include students' enthusiasm, teacher support, group cooperation, rewards, and attractive learning media, while the inhibiting factors include differences in students' abilities, limited learning time, technical problems, and differences in students' concentration levels.*

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1. INTORUDUCION

Education plays a fundamental role in developing high-quality human resources and strengthening national competitiveness in the era of globalization. The rapid advancement of science, technology, and information in the twenty-first century requires educational systems to move beyond knowledge acquisition and foster essential competencies such as

critical thinking, creativity, collaboration, communication, and problem-solving. Consequently, contemporary education is expected to cultivate lifelong learners who are capable of adapting to continuous social and technological changes.

In Indonesia, Law No. 20 of 2003 on the National Education System emphasizes that education is a deliberate and systematic effort to create learning environments in which students actively develop their intellectual, moral, spiritual, and practical competencies. Therefore, effective learning should not merely focus on academic outcomes but should also promote meaningful, student-centered learning experiences. In line with this perspective, UNESCO (2023) highlights that digital technology should be integrated into education to improve learning quality, expand educational access, and support inclusive learning environments, while maintaining the indispensable pedagogical role of teachers.

Despite continuous educational reforms, learning achievement remains a global concern. The Programme for International Student Assessment (PISA) 2022, published by the OECD (2023), revealed that students in many countries, including Indonesia, continue to demonstrate relatively low performance in mathematics, reading, and science literacy. These findings indicate that mathematical competence, particularly numeracy skills, requires substantial improvement through innovative instructional approaches capable of increasing student engagement and conceptual understanding.

Mathematics is a core subject that develops logical, analytical, and systematic thinking while serving as the foundation for science and technology. According to Van de Walle, Karp, and Bay-Williams (2019), mathematics instruction at the elementary level should emphasize conceptual understanding rather than procedural calculation alone. One of the most essential competencies is mastery of multiplication facts, which forms the basis for more advanced mathematical concepts, including division, fractions, factors, multiples, and algebraic reasoning. Students who fail to master multiplication facts often encounter persistent difficulties in higher-level mathematical learning.

However, multiplication memorization remains a significant challenge in many elementary schools. Numerous students continue to rely on repeated addition, finger counting, or other inefficient strategies to solve multiplication problems. Such dependence slows computational fluency, increases calculation errors, and negatively affects overall mathematical achievement.

Preliminary observations conducted in Grade V at SDN 3 Plampang indicated that many students experienced difficulties in memorizing multiplication facts. These difficulties were reflected in slow responses to basic multiplication questions, low confidence when answering teachers' questions, and frequent mistakes in multiplication-related calculations. Furthermore, mathematics instruction was predominantly delivered through lectures, repetitive exercises, and rote memorization, resulting in limited student participation and engagement during classroom activities.

Student motivation and active engagement are widely recognized as important determinants of academic success. Santrock (2020) argues that highly motivated learners are generally more persistent, actively involved in learning activities, and capable of achieving better academic outcomes than less motivated students. Therefore, mathematics instruction requires innovative learning models capable of simultaneously enhancing motivation and improving conceptual mastery.

One instructional approach that has gained considerable attention is gamification, which incorporates game design elements such as points, badges, levels, challenges, and leaderboards into educational contexts to increase learner motivation and engagement. Hamari, Koivisto, and Sarsa (2014) reported that appropriately designed gamification can significantly improve learning motivation and participation. Nevertheless, Dicheva et al. (2015) cautioned that gamification implemented without sound pedagogical design may

produce only temporary motivational effects without substantially improving conceptual understanding. Therefore, game elements should be integrated within pedagogically meaningful instructional models rather than functioning as isolated motivational tools.

Recent studies have suggested that gamification becomes more effective when combined with learning approaches emphasizing inquiry and problem-solving. Huang and Eguchi (2019) argued that gamification should be regarded as a pedagogical strategy rather than merely the addition of entertainment elements to instruction. One promising approach is Challenge-Based Learning, which engages students through meaningful challenges that encourage active participation, collaboration, and problem-solving. Integrating Challenge-Based Learning with gamification has the potential to create an engaging learning environment that simultaneously enhances motivation and cognitive achievement.

The rapid development of educational technology has further facilitated the implementation of gamified learning through interactive digital platforms such as Quizizz. This platform enables teachers to administer game-based quizzes featuring immediate feedback, points, rankings, and healthy competition. Recent studies have demonstrated the educational benefits of Quizizz. Zhang and Crawford (2024) found that Quizizz significantly increases students' motivation, participation, and classroom engagement. Likewise, Muchuweni, Jojo, and Kariyana (2025) reported that Quizizz effectively improves mathematics learning outcomes while providing rapid formative feedback. Similar findings were reported by Wulandari, Bharata, and Rosidin (2023), Nisa (2023), and Ardiansyah, Lestari, and Ma'ariffatun (2025), who concluded that technology-supported gamification contributes positively to students' conceptual understanding, numeracy skills, critical thinking, and academic achievement.

Although previous studies have consistently demonstrated the effectiveness of gamification, most have examined general gamified instruction without specifically integrating a Challenge-Based Gamification model. Moreover, many investigations have been conducted in urban educational settings, limiting the generalizability of their findings to schools with different educational contexts. Consequently, a research gap remains regarding the effectiveness of Challenge-Based Gamification in addressing multiplication memorization difficulties among elementary school students, particularly in SDN 3 Plampang.

To address this gap, the present study investigates the effectiveness of a Challenge-Based Gamification Learning Model in overcoming multiplication memorization difficulties among fifth-grade students at SDN 3 Plampang. Specifically, this study examines the implementation of the instructional model, evaluates its effectiveness in improving students' mastery of multiplication facts, and identifies the supporting and inhibiting factors influencing its implementation. The findings are expected to contribute both theoretically to the growing body of research on gamified mathematics instruction and practically to the development of innovative learning models for elementary mathematics education..

2. RESEARCH METHODS

This study employed a mixed-methods research design, integrating quantitative and qualitative approaches to provide a comprehensive evaluation of the effectiveness of the Challenge-Based Gamification learning model in overcoming multiplication memorization difficulties among elementary school students (Creswell & Plano Clark, 2018). The research was conducted at SDN 3 Plampang, Sumbawa, Indonesia, during the second semester of the 2025/2026 academic year. The participants consisted of 41 fourth- and fifth-grade students, selected using purposive sampling based on their identified

difficulties in memorizing multiplication facts (Creswell, 2018; Teddlie & Tashakkori, 2019).

Quantitative data were collected through pre-test and post-test assessments administered using the Quizizz platform to measure students' multiplication memorization skills before and after the intervention. The instructional model integrated challenge-based learning activities with gamification elements, including points, rewards, leaderboards, and collaborative battle challenges, to enhance students' motivation and engagement (Kapp, 2012). Qualitative data were obtained through classroom observations, semi-structured interviews with teachers and students, and documentation to explore the implementation process and identify supporting and inhibiting factors.

The quantitative data were analyzed using descriptive statistics, the Shapiro–Wilk normality test, Levene's homogeneity test, paired-sample t-test, independent-sample t-test, and N-Gain analysis to determine the effectiveness of the intervention. Qualitative data were analyzed following the interactive model of Miles, Huberman, and Saldaña (2014) through data reduction, data display, and conclusion drawing. The findings from both datasets were integrated to provide a comprehensive understanding of the effectiveness of the Challenge-Based Gamification learning model (Fetters, Curry, & Creswell, 2013).

3. RESULTS AND DISCUSSION

This section explains the research results and provides a comprehensive discussion. The discussion can be divided into several subchapters.

1.1. Research Results

The implementation of the Challenge-Based Gamification Learning Model was conducted in fourth-grade mathematics classes at SDN 3 Plampang to improve students' multiplication memorization skills. The instructional model was implemented through five sequential stages: (1) orientation and learning motivation, (2) challenge presentation, (3) game-based learning activities, (4) reward and reflection, and (5) evaluation and mastery of learning outcomes.

During the orientation stage, the teacher established students' learning readiness by explaining the learning objectives, stimulating prior knowledge, and motivating students to understand the importance of multiplication mastery in solving everyday mathematical problems. Students were then introduced to a learning environment incorporating educational games, collaborative activities, and competitive challenges.

The challenge stage consisted of progressively structured multiplication tasks designed to encourage active participation and cognitive engagement. Students completed multiplication challenges individually and collaboratively through educational card games, interactive quizzes, group discussions, and Quizizz-based activities. These activities transformed multiplication memorization into an enjoyable learning experience rather than a repetitive rote-learning exercise.

Following the completion of each challenge, students received various forms of positive reinforcement, including points, badges, verbal praise, and group recognition. Reflection activities enabled students to evaluate their learning strategies, identify remaining difficulties, and share successful memorization techniques with their classmates. Finally, posttests and formative assessments were administered to evaluate students' mastery of multiplication facts.

The descriptive statistical analysis demonstrated a considerable improvement in students' learning achievement. The experimental group (n = 20) achieved a mean pretest score of 69.25 (SD = 7.304), which increased to 83.00 (SD = 7.504) after the implementation of the Challenge-Based Gamification Learning Model. Meanwhile, the

control group (n = 21) improved from a mean pretest score of 55.71 (SD = 9.910) to a posttest mean score of 69.29 (SD = 9.783).

The assumption tests confirmed that the data met the requirements for parametric statistical analysis. The Shapiro–Wilk normality test indicated that all datasets were normally distributed ($p > .05$), while Levene's homogeneity test revealed homogeneous variances between the experimental and control groups (Sig. = .221).

The Paired Sample t-test demonstrated a statistically significant improvement between pretest and posttest scores in the experimental group ($t = –27.683$, $p < .001$), indicating that the implementation of the Challenge-Based Gamification Learning Model significantly improved students' multiplication memorization skills. Similarly, the Independent Sample t-test revealed a statistically significant difference between the experimental and control groups ($t = 5.018$, $p < .001$), confirming the superiority of the experimental treatment over conventional instruction.

The N-Gain analysis further supported these findings. The experimental group achieved an average N-Gain score of 47.19%, whereas the control group obtained only 31.53%. These findings indicate that the experimental group experienced a greater improvement in multiplication memorization than students receiving conventional instruction.

Classroom observations revealed substantial improvements in students' learning engagement, enthusiasm, collaboration, and learning motivation throughout the implementation of the instructional model. Interviews with both teachers and students consistently indicated that learning multiplication through challenges and game-based activities made mathematics lessons more enjoyable, interactive, and easier to understand. Overall, the findings demonstrate that the Challenge-Based Gamification Learning Model effectively enhanced students' multiplication memorization while creating a more engaging and student-centered learning environment.

3.2 Discussion

3.2.1 Implementation of the Challenge-Based Gamification Learning Model in Multiplication Memorization

The findings indicate that the implementation of the Challenge-Based Gamification Learning Model successfully transformed multiplication instruction into an interactive, engaging, and student-centered learning experience. Unlike conventional teacher-centered instruction, this instructional approach actively involved students throughout every phase of learning by integrating educational challenges, game mechanics, collaboration, and reflective activities.

The orientation and motivation phase played a crucial role in preparing students cognitively and emotionally for learning. Students demonstrated greater curiosity and enthusiasm after being informed that multiplication would be learned through games and structured challenges rather than traditional memorization exercises. This finding supports Keller's (2010) ARCS Motivation Model, which emphasizes that gaining learners' attention is the initial prerequisite for sustaining learning motivation. By creating an enjoyable learning atmosphere from the beginning of the lesson, the teacher successfully increased students' readiness to participate in subsequent learning activities.

The challenge stage represented the defining characteristic of the instructional model. Rather than presenting multiplication exercises as ordinary classroom tasks, the teacher transformed them into progressively structured challenges requiring students to solve problems individually and collaboratively. Such activities encouraged persistence, critical thinking, and healthy competition. These findings are consistent with Challenge-Based Learning theory proposed by Johnson and Adams (2011), which argues that

authentic and meaningful challenges stimulate deeper cognitive engagement and active problem-solving.

Game-based learning activities including multiplication card games, interactive quizzes, collaborative discussions, and Quizizz competitions created authentic learning experiences that encouraged students to practice multiplication repeatedly without perceiving the activities as monotonous drills. The incorporation of game elements significantly increased students' classroom participation, confidence, and willingness to solve mathematical problems.

These findings strongly support Kapp's (2012) theory of gamification, which defines gamification as the application of game elements in non-game contexts to increase learners' motivation, engagement, and performance. Likewise, Deterding et al. (2011) argue that gamification enhances learning experiences by integrating game mechanics capable of sustaining learner participation over extended periods.

Positive reinforcement through points, badges, and teacher recognition also contributed substantially to students' motivation. Interview data revealed that students became increasingly motivated because their achievements were publicly acknowledged. From the perspective of Skinner's (1953) operant conditioning theory, positive reinforcement strengthens desirable learning behaviors and encourages learners to repeat successful performance. Consequently, rewards functioned not merely as external incentives but also as mechanisms for building students' confidence and persistence.

Reflection activities further enhanced students' metacognitive awareness by encouraging them to evaluate their learning strategies and identify difficulties encountered during multiplication practice. According to Schraw (1998), metacognitive reflection enables learners to regulate their cognitive processes more effectively, thereby improving learning outcomes.

Overall, the five instructional stages collectively created meaningful learning experiences characterized by active participation, collaboration, enjoyment, and continuous reflection. The findings suggest that the Challenge-Based Gamification Learning Model extends beyond simply introducing games into the classroom; rather, it systematically redesigns learning experiences to foster deeper engagement and more meaningful knowledge construction.

3.2.2 Effectiveness of the Challenge-Based Gamification Learning Model in Improving Multiplication Memorization

The effectiveness of the Challenge-Based Gamification Learning Model is supported by both quantitative and qualitative evidence. Statistical analyses consistently demonstrated that students receiving the experimental treatment achieved significantly greater learning gains than those taught through conventional instruction.

The Paired Sample t-test showed a statistically significant improvement in the experimental group's posttest scores ($p < .001$), with the mean score increasing by 13.75 points. This substantial improvement indicates that the instructional intervention effectively enhanced students' multiplication memorization skills. Although the control group also exhibited improvement, the magnitude of improvement was considerably lower than that observed in the experimental group.

These findings align with Constructivist Learning Theory proposed by Piaget (1972) and Vygotsky (1978), which argues that meaningful learning occurs when students actively construct knowledge through authentic experiences. Rather than passively receiving information, students in the experimental classroom developed multiplication mastery through repeated interaction, collaborative problem-solving, educational games, and structured challenges.

The Independent Sample t-test further confirmed that students exposed to the Challenge-Based Gamification Learning Model significantly outperformed those receiving conventional instruction. This finding indicates that learning achievement is influenced not only by instructional content but also by the pedagogical strategies used to deliver that content.

The N-Gain analysis provides additional evidence supporting the effectiveness of the instructional model. The experimental group's average N-Gain score (47.19%) exceeded that of the control group (31.53%), indicating moderate instructional effectiveness. Although there remains room for improvement, these findings clearly demonstrate that challenge-based gamification facilitates greater conceptual understanding and retention of multiplication facts than traditional instructional approaches.

The observed improvement can also be explained from the perspective of motivational theory. Sardiman (2018) emphasizes that learning motivation is among the strongest determinants of academic achievement. In the present study, structured challenges, rewards, competition, and collaborative learning increased students' willingness to participate actively, thereby enhancing both cognitive engagement and learning persistence.

From the perspective of Information Processing Theory (Atkinson & Shiffrin, 1968), repeated retrieval of multiplication facts during games and quizzes strengthened memory encoding and long-term retention. Students repeatedly practiced multiplication in enjoyable contexts, allowing rehearsal processes to occur naturally rather than through forced memorization. Consequently, students demonstrated greater fluency and confidence when solving multiplication problems.

The qualitative findings reinforce the quantitative evidence. Classroom observations showed noticeable increases in participation, collaboration, and enthusiasm throughout the intervention. Interviews further revealed that students perceived multiplication learning as enjoyable rather than intimidating. Teachers likewise observed improvements in students' confidence, participation, and speed in recalling multiplication facts.

These findings are consistent with Hamari, Koivisto, and Sarsa (2014), whose meta-analysis concluded that gamification positively influences motivation, engagement, and learning outcomes across educational settings. Similarly, Gee (2013) argues that game-based learning environments promote active learning, problem-solving, and meaningful knowledge construction.

Collectively, the statistical analyses, classroom observations, and interview findings provide compelling evidence that the Challenge-Based Gamification Learning Model effectively improves students' multiplication memorization. The convergence of quantitative and qualitative evidence strengthens the validity of the conclusion that integrating challenge-based and game-based instructional strategies significantly enhances mathematics learning outcomes.

3.2.3 Supporting and Inhibiting Factors Affecting the Implementation of the Challenge-Based Gamification Learning Model

The successful implementation of the Challenge-Based Gamification Learning Model was influenced by several supporting and inhibiting factors identified through classroom observations and interviews.

The primary supporting factor was students' high level of enthusiasm. Throughout the intervention, students actively participated in games, challenges, discussions, and collaborative learning activities. Their willingness to engage voluntarily reflected increased intrinsic motivation, which positively influenced learning achievement. According to Sardiman (2018), motivated learners exhibit greater persistence,

concentration, and commitment toward academic tasks, ultimately leading to improved educational outcomes.

Another important supporting factor was the implementation of a reward system. Students reported that points, badges, and teacher recognition encouraged them to complete learning challenges enthusiastically. Positive reinforcement promoted healthy competition while simultaneously strengthening students' confidence and willingness to participate. This finding supports Skinner's theory that reinforcement increases the likelihood of desirable behavioral repetition.

Teacher support also played an indispensable role in facilitating successful implementation. Teachers acted not only as knowledge transmitters but also as facilitators, motivators, and classroom managers. Effective guidance ensured that all students remained actively involved regardless of their individual learning abilities.

Collaborative learning further contributed to instructional success. Students exchanged ideas, solved problems collectively, and supported peers experiencing learning difficulties. These collaborative interactions align with Vygotsky's (1978) social constructivist perspective, emphasizing that knowledge develops through meaningful social interaction.

The use of engaging instructional media including multiplication cards, interactive quizzes, and Quizizz also enhanced students' learning experiences. These instructional tools transformed repetitive multiplication practice into enjoyable learning activities while maintaining students' sustained attention.

Despite these strengths, several implementation challenges were identified. Students demonstrated varying levels of prior mathematical ability, requiring teachers to provide differentiated instructional support. Time management also emerged as a significant concern because each instructional phase including challenges, games, reflection, and evaluation—required substantial classroom time.

Technical limitations occasionally disrupted technology-supported learning activities. Unstable internet connectivity and limited digital devices reduced the effectiveness of Quizizz sessions. Furthermore, differences in students' attention spans required continuous teacher supervision to ensure active participation throughout the learning process.

Although these challenges were evident, they did not substantially reduce the overall effectiveness of the instructional model. Instead, they highlight practical considerations for future implementation, including improved classroom management, differentiated instruction, flexible scheduling, and adequate technological infrastructure.

Overall, the findings indicate that the successful implementation of the Challenge-Based Gamification Learning Model resulted from the interaction of multiple factors, including student motivation, teacher facilitation, collaborative learning, engaging instructional media, and positive reinforcement. While practical challenges remain, the instructional model demonstrates considerable potential for improving mathematics learning in elementary education, particularly in developing students' multiplication memorization skills through enjoyable, meaningful, and student-centered learning experiences..

4. CONCLUSION

Based on the data analysis and discussion presented in the preceding chapter, this study concludes that the implementation of the Challenge-Based Gamification Learning Model was successfully carried out in teaching multiplication memorization to students at SDN 3 Plampang through five sequential stages: orientation and learning motivation, challenge presentation, game-based learning activities, reward and reflection, and

evaluation of learning outcomes. The findings from classroom observations and interviews indicate that this instructional model created a more active, interactive, and enjoyable learning environment, thereby enhancing students' motivation and engagement in learning multiplication. Furthermore, the Challenge-Based Gamification Learning Model was proven to be effective in improving students' multiplication memorization skills. The Paired Sample t-test revealed a statistically significant difference between the experimental group's pretest and posttest scores ($p < .001$), while the Independent Sample t-test demonstrated a significant difference in learning outcomes between the experimental and control groups ($p < .001$). These findings were further supported by the N-Gain analysis, which showed that the experimental group achieved an average gain score of 47.19%, categorized as moderately effective, whereas the control group obtained an average gain score of 31.53%, categorized as less effective. These results confirm that the Challenge-Based Gamification Learning Model is more effective than conventional instruction in enhancing students' multiplication memorization skills. The study also identified several factors influencing the implementation of the instructional model. Supporting factors included students' high enthusiasm, the use of rewards to enhance learning motivation, continuous teacher support, effective group collaboration, and engaging instructional media. In contrast, the primary challenges involved differences in students' learning abilities, limited instructional time, technical constraints associated with technology-based learning media, and variations in students' concentration levels. Despite these challenges, the supporting factors were found to outweigh the barriers, enabling the successful implementation of the Challenge-Based Gamification Learning Model and contributing positively to students' multiplication memorization and overall mathematics learning outcomes.

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