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The Application of Gamification to Elementary School Students' Understanding of Mathematical Concepts

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ABSTRACT

The low level of Mathematical concept understanding among elementary school students remains a problem influenced by the use of teaching methods that tend to be conventional. This study aims to analyze the effect of gamification on the Mathematical concept understanding of third-grade elementary school students. This study used a quantitative approach with a pre-experimental method through a One-Group Pretest-Posttest Design. The research subjects were 21 third-grade elementary school students. Data were collected through tests and documentation. The research instruments included pretest and posttest questionnaires. The data were analyzed using descriptive analysis and a statistical test specifically, a paired-sample t-test to determine the effect of gamification on students' conceptual understanding. The implementation of gamification elements such as experience points, badges, levels, challenges, and rewards was able to create a more enjoyable and interactive learning environment. The results showed that the average pretest score increased from 66.29 to 81.62 in the posttest, indicating that the application of gamification improved the understanding of Mathematics concepts. The results of the Paired Sample t-Test obtained a significance value of <0.001 meaning the sig value <0.05, thus indicating that there was a statistically significant difference between the pre-test and post-test scores. These findings confirm that the implementation of gamified learning had a significant positive effect on improving the mathematical conceptual understanding of third-grade elementary school students.

Keywords: *gamification; game mechanics in education; mathematical concepts; elementary school*

INTRODUCTION

Elementary education is the cornerstone of character development and critical thinking skills in students. At the elementary school level, students go through a critical transitional phase for their intellectual and emotional development. One of the subjects considered fundamental in education is Mathematics (Wiraprana & Surya, 2022). Mathematics not only plays a role in honing logical thinking but also helps students solve various problems systematically. However, in practice, Mathematics is often perceived by most students as difficult, boring, and uninteresting. This situation leads to low student motivation and negatively impacts their academic performance. These issues are

also reflected in national and international assessments. The 2022 PISA results show that Indonesian students' Mathematical literacy remains well below the OECD average (OECD, 2023).

Therefore, there is an urgent need for innovation in Mathematics teaching methods so that students are not only able to understand concepts but also find enjoyment in the learning process. One creative approach that is now increasingly popular and widely applied in education is gamification. Gamification is the application of game elements in non-game contexts, including education. These elements include experience points, badges, levels, challenges, and rewards, all of which are designed to increase user participation, motivation, and engagement (Ariyanto et al., 2023; Kam & Umar, 2023). In the learning process, gamification aims to create a more engaging, challenging, and interactive learning experience (Agus & Kusuma Wardhani, 2023). The application of gamification in teaching Mathematics in elementary schools is believed to bring a fresh perspective to the learning process, which has long been considered monotonous and burdensome for students.

Gamification is an effective learning strategy for increasing student motivation. However, to optimally achieve educational goals, the implementation of gamification requires continuous evaluation and adjustment (Azman & Bakhtiar, 2024; Yusri & Zainal, 2025). While it offers various benefits in the learning process, the success of gamification implementation is greatly influenced by careful planning, a comprehensive understanding of student characteristics, and the development of learning activities relevant to learning goals and needs (Umar & Wiguna, 2020). A review of various studies shows that gamification has a positive impact on increasing learning motivation, student engagement in the learning process, and overall learning outcomes.

Student engagement is a concept that refers to students' behaviors, attitudes, and level of participation in academic activities. High engagement is characterized by students' attention, effort, and active contributions to the learning process. The use of gamification strategies can increase student engagement, especially in collaborative activities and interactions between students and teachers (Ruiz, 2024). These findings are supported by various studies showing that the implementation of gamification contributes to increased student engagement in learning. Students engaged in gamified learning tend to participate more actively, are more productive in completing tasks, and demonstrate more intense interaction with the learning material compared to students who participate in learning without gamification elements (Luo, 2022).

Gamification has been shown to increase students' motivation to learn and to have a positive impact on the learning process and outcomes. However, the effects of gamification are not always the same for every student. A study conducted by Kam and Umar (2022) involving 118 students in Malaysia showed that academic achievement levels influence the effectiveness of gamification-based learning. In that study, students with high, moderate, and low academic achievement demonstrated different responses to the implementation of gamification. The study measured several aspects of motivation, namely self-confidence in one's abilities (competence), intrinsic motivation, valuation, and engagement in learning. The results indicate that academic achievement

levels influence the effectiveness of gamification, particularly regarding valuation—the perception of the value and benefits of learning. These findings suggest that the implementation of gamification should account for differences in students' academic characteristics to maximize the benefits derived (Kam & Umar, 2023).

Improvements in the quality of education in recent years are closely linked to the implementation of the Merdeka Curriculum Policy, supported by the integration of technology into the learning process (Azman & Bakhtiar, 2024). In this context, gamification has emerged as an innovative approach with the potential to boost learning motivation, student engagement, and the attainment of learning competencies. Nevertheless, the implementation of gamification at the elementary school level still faces various obstacles. Key challenges in gamification include limited digital competencies among educators, a lack of ongoing professional development programs, limited technological infrastructure, the complexity of developing gamification-based learning materials, and insufficient institutional support. These challenges require serious attention as they can affect the effectiveness of gamification in supporting the achievement of learning objectives.

Several previous studies have shown that gamification has a positive impact on the learning process and outcomes. The implementation of gamification has been shown to increase learning motivation, student engagement, collaboration, and learning outcomes across various educational levels and subjects. A learning environment that combines game elements with learning objectives can create a more enjoyable learning atmosphere, encouraging students to be more active in building their knowledge and understanding the material being studied. In addition, providing immediate feedback, rewards for achievements, and challenges tailored to students' abilities can boost their self-confidence and encourage them to continue improving their learning outcomes.

Nevertheless, most research on gamification still focuses on improving learning motivation, student engagement, or learning outcomes in general. Research that specifically examines the effect of gamification on elementary school students' understanding of Mathematical concepts particularly in the lower grades remains relatively limited. At this stage, students are building the basic Mathematical concepts that will serve as the foundation for learning at the next level. Therefore, this study was conducted to analyze the effectiveness of gamified learning on third-grade elementary school students' understanding of Mathematical concepts. The results of this study are also expected to serve as a reference for teachers in designing more engaging, interactive, and student-centered Mathematics lessons to improve the understanding of Mathematical concepts in elementary school.

METHOD

This study employs a quantitative approach using an experimental method. The quantitative approach was chosen because the study aims to measure the effect of gamification on elementary school students' understanding of Mathematical concepts through numerical data analyzed statistically.

The experimental method was used to determine the cause-and-effect relationship between the independent and dependent variables. In this study, the independent variable was the application of gamification, while the dependent variable was students' understanding of Mathematical concepts.

The research design used is a pre-experimental design in the form of a one-group pretest-posttest design. In this design, the research subjects are given a pretest before the treatment and a posttest after the treatment is administered. Thus, the researcher can determine the changes that occur after the application of gamification in Mathematics learning. The research design can be illustrated as follows:

Pretest	Treatment	Posttest
O_1	X	O_2

Keterangan:
O_1 : *Pre-test* (test before the implementation of gamification)
X : Treatment involving the implementation of gamification in Mathematics instruction
O_2 : *Post-test* (test after the implementation of gamification)

The study was conducted on 21 third-grade students at SDIT An-Nahl Bandar Lampung. Saturated sampling was used as the sampling technique, as the entire population was used as the sample. The implementation of gamification-based learning in this study was carried out over six meetings. Treatment was provided consistently at each meeting by integrating gamification elements into the learning process, such as experiences, badges, levels, challenges, and rewards.

The research instrument was a mathematical concept understanding test sheet given before (pre-test) and after treatment (post-test). The test instrument was adopted from previous research that has met the validity and reliability criteria so it is suitable for use to measure students' mathematical concept understanding abilities (Rahmaini & Surayanah, 2026). The results of the material expert validity test on the instrument showed a percentage of 97.90% with a very valid category, while the results of the instrument expert validation test obtained a percentage of 99% with a very valid category, indicating that the question construct, grid and scoring rubric have met the rules for compiling assessment instruments. The results of the instrument reliability test were 0.932, indicating that the test instrument has a very high level of consistency. The adopted question instrument has the following question indicators (Rahmaini & Surayanah, 2026):

Table 1. Indicators of Mathematical Concept Understanding Questions

No.	Question Indicator
1	Students solve addition problems correctly and fluently and provide simple explanations of the steps used.
2	Students analyze in detail the subtraction steps used to obtain the final result.
3	Students combine several multiplication strategies in one problem solution.
4	Students draw conclusions from the division process based on the steps used.

The test indicators were designed to measure students' understanding of mathematical concepts in arithmetic operations. Measurement was conducted through the ability to apply addition concepts, analyze subtraction procedures, combine multiplication strategies, and draw conclusions from division processes. These four indicators assess not only the accuracy of the results but also the students' comprehensive understanding of mathematical concepts.

Data analysis was conducted using descriptive and inferential statistics. Descriptive statistics were used to describe the mean, maximum, minimum, and standard deviation scores. Prior to hypothesis testing, the data were tested for normality using the Shapiro-Wilk test, followed by a homogeneity test. After all parametric test assumptions were met, a paired sample t-test was conducted to determine the difference in pre-test and post-test scores in students' mathematical concept understanding after the implementation of gamification-based learning. Decision-making was based on a 2-tailed significance value (Sig.) at a significance level of 0.05. If the Sig. (2-tailed) < 0.05, then the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted, indicating a significant difference between the pretest and posttest scores. Conversely, if the Sig. (2-tailed) value ≥ 0.05, then the null hypothesis (H_0) is accepted and the alternative hypothesis (H_a) is rejected, indicating there is no significant difference between the pretest and posttest scores.

FINDINGS AND DISCUSSION

a. Description of the Implementation of Gamified Learning

Gamification-based learning is implemented after students complete a pre-test to determine their initial understanding of mathematical concepts. The implementation of gamification-based mathematics learning was carried out over six meetings by applying various game elements into teaching and learning activities. Gamification-based mathematics learning is implemented by incorporating various game elements into teaching and learning activities. At the beginning of the lesson, the teacher explains the learning objectives and the game rules that will be used throughout the learning process. Students are given an explanation of the game rules, the experience points system, badges, levels, challenges, and rewards that can be earned upon successfully completing each learning activity. The teacher also explains that each student has an equal opportunity to earn rewards based on their effort and involvement during the learning process, not solely on the final result.

The core activity begins with a brief presentation of the material using instructional media supplemented by contextual illustrations to build students' initial understanding. Next, students are divided into small, heterogeneous groups of four to five students based on academic ability. The purpose of grouping students in this way is to encourage cooperation, communication, and mutual assistance in solving each challenge presented.

After receiving an explanation of the material, students participated in a series of gamified activities designed in stages. Each group was given a mission to solve problems

testing their understanding of Mathematical concepts, with the difficulty level increasing at each stage. The problems not only required computational skills but also assessed students' ability to explain concepts, identify the properties of a concept, provide examples and counterexamples, and apply concepts to real-life situations. Each correct answer earns a certain number of points that are immediately recorded on the scoreboard so that students can track their group's progress.

Throughout the learning process, the teacher provides immediate feedback on students' answers. If an answer is incorrect, the teacher does not immediately provide the correct answer but instead offers hints and probing questions so that students can discover the correct concept on their own. This feedback mechanism aims to strengthen conceptual understanding while developing students' thinking skills.

To boost motivation to learn, each group that successfully completes a level receives a badge as a token of appreciation for their achievement. In addition, the teacher displays a leaderboard that is updated periodically based on the total points earned by each group. The leaderboard fosters healthy competition among the groups while also increasing student participation during the lesson. The teacher continues to emphasize that the main goal of the activity is to understand Mathematical concepts, not simply to be the group with the highest score.

At the end of each session, the teacher and students reflect on the learning activities. Students are given the opportunity to share their learning experiences, the difficulties they encountered, and the strategies they used to overcome challenges. The teacher then reinforces the key concepts that have been learned and connects them to the material to be covered in the next session.

Overall, the implementation of gamification-based learning went well. During the learning activities, students showed great enthusiasm in taking on each challenge presented. Group discussions were more active than in conventional learning, as evidenced by the increased frequency with which students asked questions, expressed their opinions, and explained the reasoning behind their answers. In addition, students appeared more confident in solving math problems because they received immediate feedback and recognition for every bit of progress they made.

After the entire learning sequence was completed, the students took a post-test using the same instrument as the pretest to measure changes in their understanding of Mathematical concepts following the gamification-based learning intervention. The posttest results were then analyzed to determine the effectiveness of gamification in improving elementary school students' understanding of Mathematical concepts.

b. Level of Understanding of Mathematical Concepts Based on Pre-test and Post-test Scores

Concept comprehension tests were administered before and after the implementation of gamification to assess improvements in third-grade elementary school students' understanding of Mathematical concepts.

Table 2. Pre-Test and Post-Test Scores

		Mean	N
Pair 1	Pre Test	66.29	21
	Post Test	81.62	21

The pretest results showed that students' understanding of Mathematical concepts prior to the implementation of gamification was still relatively low. The students' average pretest score was 66.29. This indicates that previous instruction had not yet fully enabled students to understand Mathematical concepts optimally.

After implementing gamification, the post-test results showed an improvement in the students' understanding of Mathematical concepts. The students' average post-test score increased to 81.62. This improvement indicates that the implementation of gamification had a positive impact on the third-grade elementary school students' understanding of Mathematical concepts.

Next, the data underwent a normality test to determine whether the distribution pattern met the assumption of normality. If the data is normally distributed, it means that parametric analysis techniques, such as the t-test, can be used. Since the data is evenly distributed around the midpoint (mean), we processed the data using the Shapiro-Wilk test in SPSS because the sample size was less than 50. The following is a summary of the normality test results.

Table 3. Tests of Normality

Exam Scores	Shapiro-Wilk		
	Statistic	df	Sig.
Pre Test	.950	21	.344
Post Test	.926	21	.114

The results of the normality test show that the significance value for the pretest was 0.344 and for the posttest was 0.114. All of these significance values are greater than 0.05 both for the pretest (0.344 > 0.05) and the posttest (0.114 > 0.05) so the pretest and posttest data are deemed to be normally distributed. Thus, the assumption of normality has been met, and the analysis of homogeneity can proceed.

Table 4. Tests of Homogeneity of Varience

		Levene Statistic	df1	df2	Sig.[a]
Nilai Ujian	Based on Mean	2,544	1	40	0,119
	Based on Median	2,726	1	40	0,107
	Based on Median and with adjusted df	2,726	1	37,039	0,107
	Based on trimmed mean	2,527	1	40	0,120

The results of the homogeneity test using Levene's Test showed a significance value of 0.119. Since the significance value is greater than 0.05 (0.119 > 0.05), the data variances are considered homogeneous. Based on the results of the normality and homogeneity tests, it can be concluded that the research data meet the basic assumptions

of parametric analysis. Therefore, further analysis can be conducted using a paired-sample t-test to determine significant differences between the pretest and posttest scores of third-grade elementary school students.

Table 5. Paired Samples Test

				95% Confidence Interval of the Difference				Significance	
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pre Test - Post Test	-15.333	4.673	1.020	-17.460	-13.206	-15.038	20	<,001	<,001

The results of the paired-sample t-test show a significant difference between students' understanding of Mathematics material before and after the implementation of gamified learning. As shown in the table, based on the analysis conducted using the paired-sample t-test, it can be concluded that the significance level (Sig., 2-tailed) is <0.001. Therefore, the null hypothesis (Ho) is rejected and the alternative hypothesis (Ha) is accepted. Thus, there is a significant difference between students' learning outcomes before and after the implementation of gamified learning. It can therefore be concluded that the implementation of gamification is effective in improving third-grade elementary school students' understanding of Mathematical concepts.

DISCUSSION

The findings of this study support the use of gamification in elementary school learning. This is consistent with a study (Indarti & Sunanto, 2026) that analyzed 15 selected journal articles on the implementation of gamification in learning. The pedagogical impact highlights the effects of gamification on student motivation, active participation, conceptual understanding, and creative thinking skills. Of the 15 studies, 10 reported an increase in student motivation, 9 reported improved learning outcomes, and 5 showed an improvement in creative thinking skills. Gamification was implemented through elements such as points, levels, badges, challenges, rewards, narratives, and interactive game-based activities, which were shown to increase student engagement and enjoyment.

In general, students expressed positive perceptions toward the use of gamification in Mathematics instruction. The use of gamification elements can increase learning motivation, encourage active student engagement during the learning process, and create a more enjoyable learning environment. Students found the learning experience to be more engaging, interactive, and less boring compared to conventional instruction. These conditions provide a more meaningful learning experience, thereby supporting improved understanding of Mathematical concepts (Adenike Omonijo Toromade et al., 2024; Hayati & Nuraina, 2025; Mursalin et al., 2024; Syuhada et al., 2023).

One key aspect of gamification is the use of real-time feedback. In traditional classrooms, feedback is often delayed, with students receiving corrections long after

completing an assignment or test. However, in gamified learning, feedback is provided immediately, allowing students to correct their mistakes and learn from them in real time (Abarca et al., 2023; Lutviana et al., 2025). This constant cycle of feedback is crucial for building a deeper understanding of Mathematical concepts, as it helps students identify where they went wrong and adjust their approach. By providing instant feedback, gamification minimizes the frustration that often accompanies challenging subjects like Mathematics and keeps students engaged in the learning process (Byusa et al., 2022).

In addition, gamified learning often adjusts the difficulty level of problems to each student's individual ability. This personalization ensures that students are always working at the right level of challenge, preventing boredom from tasks that are too easy or frustration from problems that are too difficult. Adaptive learning systems use data analytics to track student performance and adjust learning paths in real time, ensuring that each student receives a tailored educational experience. As a result, students who may struggle with math are given the support they need to succeed, while high-achieving students continue to be challenged to reach their full potential (Gini et al., 2025; Lee et al., 2023).

In addition to academic improvement, gamification also fosters students' social and collaborative skills. Team-based activities and healthy competition encourage interaction among students, strengthen cooperation, and build communication skills. This process not only enhances individual intrinsic motivation but also creates a dynamic, positive learning community that supports students' emotional development. Students who were previously reluctant to participate in math class have become more enthusiastic, are more willing to take risks when attempting new problems, and demonstrate greater perseverance when facing challenges (Ansori et al., 2025; Maragañas & Dioso, 2025).

Nevertheless, the effectiveness of gamification is greatly influenced by the quality of instructional design. Therefore, the implementation of gamification must be tailored to students' characteristics, needs, and ability levels. Furthermore, a balance must be struck between the use of game elements and the achievement of learning objectives so that learning activities do not focus solely on entertainment but also optimally foster conceptual understanding (Kode, 2025; Romero-Rodríguez et al., 2024).

Based on the research findings, there are several implications that can be applied to Mathematics instruction in elementary school. Teachers need to design inclusive gamification-based learning so that all students have equal opportunities to participate without feeling burdened by competition. Elements of gamification such as points, badges, levels, challenges, and rewards should be integrated in a balanced manner and aligned with learning objectives so that they can boost motivation while deepening students' understanding of Mathematical concepts.

The successful implementation of gamification also requires support from the school, particularly in providing learning facilities and infrastructure, including the use of technology as a supporting medium. Such support will make it easier for teachers to implement gamification effectively and sustainably, thereby having a more optimal impact on improving the quality of Mathematics education in elementary schools.

CONCLUSION

This study concluded that the implementation of gamification-based learning is effective in improving third-grade elementary school students' understanding of Mathematical concepts. The results of the analysis, using a paired-sample t-test, showed a significant difference between pretest and posttest scores, with a significance level (Sig., 2-tailed) of 0.001 (< 0.05). These findings indicate that gamification-based learning has a positive impact on improving students' understanding of Mathematical concepts. This improvement in conceptual understanding occurs because the implementation of gamification elements such as experience points, badges, levels, challenges, and rewards increases student engagement during the learning process. A more enjoyable learning environment encourages students to participate actively, understand concepts gradually, and complete learning tasks with greater enthusiasm. Thus, gamification can serve as an innovative alternative learning strategy to support Mathematics education in elementary schools.

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