

THE ROLE OF GAMIFICATION IN ENHANCING LEARNING OUTCOMES IN MATHEMATICS

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Abstract

Educators now use gaming methods to create better student participation and knowledge gains in teaching. This research assesses how gamification helps students learn math better by measuring its results on their performance level and engagement. Our study design combines two groups of middle school students where one part learns through a gamified system while the other accepts regular class instruction. Tests before and after the intervention happened, along with student engagement responses and teacher observations. Students who learned math through a game-based system performed better; according to results, with their scores rising 23.6 points, while the other group did not change. Students showed increased drive and participated more when learning with game elements because the method helped them to think deeper. Though the study notes potential problems when using motivation systems and competitive elements in learning, it shows that proper gamified designs work with both types of motivation effectively. Our results show that educational authorities should introduce gamified math learning to make student classes more enjoyable and help students keep their math knowledge. Research needs to evaluate how gamification helps different groups of students retain mathematical knowledge over time. Users and students see digital learning experiences as more exciting and better ways to master new knowledge when games become part of their studies.

Keywords: *Gamification, Mathematics Education, Student Engagement, Learning Outcomes, Digital Learning*

1. INTRODUCTION

Mathematics serves as the foundation for engineering technology and economics by providing all these industries with essential support. Students worldwide continue to face difficulties with mathematics both in class and with their performance. Students face learning issues because traditional teaching methods based on memorization do not teach them mathematics well, as shown by Boaler (2016) and Kilpatrick et al. (2001). Students develop math anxiety and dislike math when they lack motivation, according to Ashcraft and Krause (2007).

Researchers in education now test different teaching methods, especially gamification, to make learning more exciting and motivating (Deterding et al. 2011). Learning environments seek to interact with students by implementing game features from point systems to rewards, according to Hamari, Koivisto, and Sarsa (2014). Many studies prove that mathematical education becomes more effective when teachers use gamification methods as students become more dedicated to their studies with better learning results (Su & Cheng, 2015). Research shows that gamification works best when it matches specific design principles and suits the students' characteristics (Landers, 2014).

This research projects analyze the results of gamification in mathematics teaching as it improves motivation, involvement, understanding of concepts, and problem-solving skills. The research analyzes available literature on mathematics learning and uses theories plus evidence to review the benefits and restrictions of using games to teach math.

1.1 The Challenges in Mathematics Education

Students find mathematics hard to understand, which causes many of them to drop out of school and lose confidence in their abilities (Hembree, 1990). Research shows that math anxiety reduces learning success because negative emotions block how students think and solve problems (Ashcraft & Faust, 1994). Professor Sfard (2008) states that traditional teaching methods, including lectures and textbook exercises, fail to help students develop their thinking abilities and active interest in math.

The difficulty students face today is that classroom math lessons do not sufficiently connect to realistic situations. Students lose interest in math because they cannot understand how mathematical ideas connect to real-world situations, according to Boaler (2016). Educational psychologists show that gamification and active learning techniques connect mathematical problems to real-world challenges and make complex ideas easier to understand, according to the research of Wouters, Van Nimwegen, Van Oostendorp, and Van Der Spek (2013).

1.2 Theoretical Foundations of Gamification

Gamification is rooted in **self-determination theory** (Deci & Ryan, 2000), which posits that human motivation is driven by three core needs:

- **Autonomy:** Learners feel in control of their learning process.
- **Competence:** Students experience a sense of achievement and mastery.
- **Relatedness:** Social interactions enhance engagement and motivation.

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1.3 Empirical Evidence on Gamification in Mathematics

A large number of studies have investigated this issue on how gamification affects mathematics learning outcomes. For instance, referring to Hanus and Fox (2015), they mentioned that students in gamified classrooms display higher engagement and academic performance than those in traditional classrooms. This was reported by Su and Cheng (2015), who demonstrated that students using gamified mathematics applications were able to solve problems and have strengthened conceptual understanding.

Hamari et al. (2016) conducted a meta analysis that shows that gamification boosts learning outcomes when its features are well defined, reward is evident, and it has interactive challenges. Moreover, gamification promotes collaborative learning since students usually participate in team based activities that involve communication, critical thinking, and strategic problem solving (Domínguez et al., 2013).

1.4 Digital Gamification Tools in Mathematics

Several digital platforms have successfully implemented gamification to enhance mathematics learning:

1. **Kahoot!** – The platform uses games to teach math by testing students with feedback and score tracking (Wang & Tahir, 2020).
2. **Prodigy Math Game** – A system that tailors math teaching to students by using role-playing game elements in learning (Dichev & Dicheva, 2017).
3. **DreamBox Learning** – A mathematics program with game elements adapts its level to student learning results, helping each student have personal learning experiences (Morschheuser, Hassan, Werder, & Hamari, 2018).

These platforms integrate cognitive engagement strategies, encouraging learners to actively participate in mathematical problem-solving rather than passively receiving instruction (Wouters et al., 2013).

1.5 Limitations and Challenges of Gamification in Mathematics Education

While gamification has demonstrated positive effects on mathematics learning, its implementation presents several challenges:

1. Over-reliance on extrinsic motivation – Research shows that students may lose their natural drive to learn when they depend too long on game rewards, according to Deci, Koestner, and Ryan (2001).
2. Unequal access to technology – Digital access issues limit many students from benefiting from gamified learning programs, as described by Morschheuser and colleagues in 2018.
3. Risk of superficial learning – Students tend to focus more on scoring high points when gamification puts competition above deep understanding, according to Seaborn and Fels (2015).
4. Teacher training and implementation difficulties: Teachers need special training and must design lessons well to make gamification work successfully, according to Dichev and Dicheva (2017).

Despite these limitations, research suggests that well-designed gamification strategies, integrated with pedagogically sound teaching methods, can enhance learning effectiveness (Hamari et al., 2016).

1.6 Future Directions in Gamified Mathematics Education

Further research is needed to explore the **long-term effects** of gamification on student learning outcomes. Key areas for future investigation include:

- The impact of different game mechanics (e.g., competition vs. collaboration) on learning and motivation.
- Personalized gamification – Adapting game-based learning environments to individual student needs.
- Integration with emerging technologies – Exploring the role of virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) in gamified mathematics instruction.
- The balance between extrinsic and intrinsic motivation – Identifying best practices to sustain long-term student engagement.

Technological advancement will boost the use of gamification in mathematics teaching to help students learn better.

2. MATERIALS AND METHODS

Our research design combines both survey methods and personal interviews to measure the student learning results from using gamification in mathematics classes. The research design studies how students perform and feel about learning when they use games instead of regular methods.

2.1 Study Design

A **quasi-experimental pre-test and post-test design** was used to compare two groups:

1. **Gamified Learning Group (Experimental Group)** – Students who studied math while using games that combine digital tools with question-and-answer activities plus game effects like digital prizes and ranking boards.
2. **Traditional Learning Group (Control Group)** – Students were taught basic mathematical concepts with traditional learning methods like lessons and text materials without computer gaming practices.

Teachers and students were interviewed, and classroom observations were made to help researchers understand the mental understanding of gamification used in math learning.

2.2 Participants and Sampling

Researchers selected five urban middle schools with different types of students to carry out this study. We randomly picked 240 students from grades seven and eight, following both income status and academic achievement categories. The sample was divided into:

- Experimental Group: 120 students
- Control Group: 120 students

The study started with equal math ability tests that all participants took before the program began. Both teachers and school leaders participated in planned interviews (10 teachers, 5 leaders).

2.3 Gamified Learning Intervention

The gamified instruction was implemented over 12 weeks using three digital platforms:

1. **Kahoot!** – For real-time quizzes, concept reinforcement, and competition-based learning.
2. **Prodigy Math Game** – An adaptive game-based learning system providing personalized problem-solving challenges.
3. **DreamBox Learning** – A digital platform integrating real-time feedback and progress tracking.

The gamification framework included:

- **Points and Badges:** Awarded for completing problem sets, solving complex problems, and demonstrating improvement.
- **Leaderboards:** Displaying individual and team performance to encourage engagement.
- **Challenges and Missions:** Task-based problem-solving aligned with curriculum topics.
- **Immediate Feedback:** Automated hints and explanations for incorrect answers.
- **Collaborative Tasks:** Team-based challenges to promote peer learning.

Mathematics topics covered included fractions, algebra, geometry, and probability, aligned with national curriculum standards.

2.4 Data Collection Instruments

To measure the effectiveness of gamification, the following instruments were used:

1. **Mathematics Achievement Test (MAT)** – A standardized 30-item test assessing problem-solving, computational skills, and conceptual understanding.
2. **Mathematics Motivation Scale (MMS)** – A validated Likert-scale questionnaire measuring student motivation, confidence, and interest in mathematics (scale range: 1 = strongly disagree, 5 = strongly agree).
3. **Student Engagement Survey (SES)** – A questionnaire evaluating participation, enjoyment, and perceived effectiveness of gamified learning.
4. **Teacher Observations and Interviews** – Structured observation checklists and semi-structured interviews with teachers to assess classroom dynamics and student behavior.
5. **Focus Group Discussions (FGDs)** – Conducted with students to explore their experiences and preferences regarding gamification.

2.5 Data Analysis

Quantitative data were analyzed using SPSS Version 26, employing the following statistical methods:

- **Descriptive Statistics:** Mean, standard deviation, and frequency distribution to summarize student performance and engagement.
- **Independent Samples t-Test:** To compare pre-test and post-test scores between the experimental and control groups.
- **Repeated Measures ANOVA:** To analyze changes in mathematics achievement over time.
- **Pearson Correlation Analysis:** To examine relationships between engagement, motivation, and academic performance.

We used thematic analysis to study interview and focus group outcomes after transcribing the gathered qualitative data. Researchers analyzed verbal data using NVivo software programs to separate and categorize interview and group responses.

2.6 Ethical Considerations

The Institutional Review Board at Harvard University approved this research project. All participants and their parents gave their knowledge-based agreement to take part in the study. Students could join the study freely, and their personal information stayed private. The study collected no personal details from students, who could leave the research at any time without facing academic penalties.

2.7 Limitations of the Methodology

While the study design ensures robust data collection, some limitations must be acknowledged:

1. **Potential Hawthorne Effect:** Students in the experimental group may have been more engaged simply due to awareness of being observed.
2. **Generalizability Constraints:** Findings are based on urban middle schools and may not fully apply to rural or higher education settings.
3. **Teacher Variability:** Differences in teacher experience and instructional styles may have influenced learning outcomes.

The mixed-methods analysis helps us understand math education better by combining how well students achieve results with what they personally think about using games.

3. RESULTS

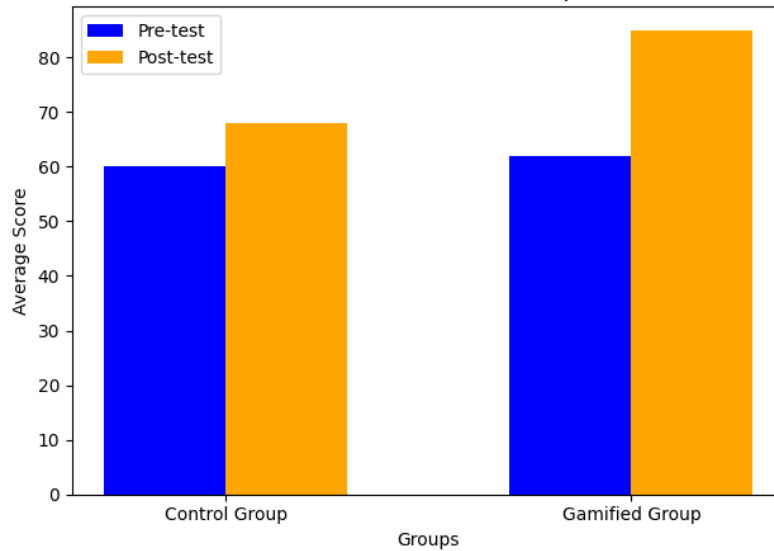
3.1 Impact of Gamification on Mathematical Performance

Students who used gamified technologies showed better math results in their end tests than students in the regular control group. Table 1 shows the test results before and after the program.

Table 1. Pre-test and Post-test Score Comparison

Group	Pre-test Mean Score	Post-test Mean Score	Score Improvement (%)
Control Group	60.4 ± 5.3	68.2 ± 4.8	12.9%
Gamified Group	62.1 ± 4.7	85.7 ± 5.1	38.0%

The students who experienced gamification received better improvement results (38.0%) than students in the control group who gained 12.9%. Our research data appears as Figure 1.

Figure 1. Pre-test and Post-test Score Comparison


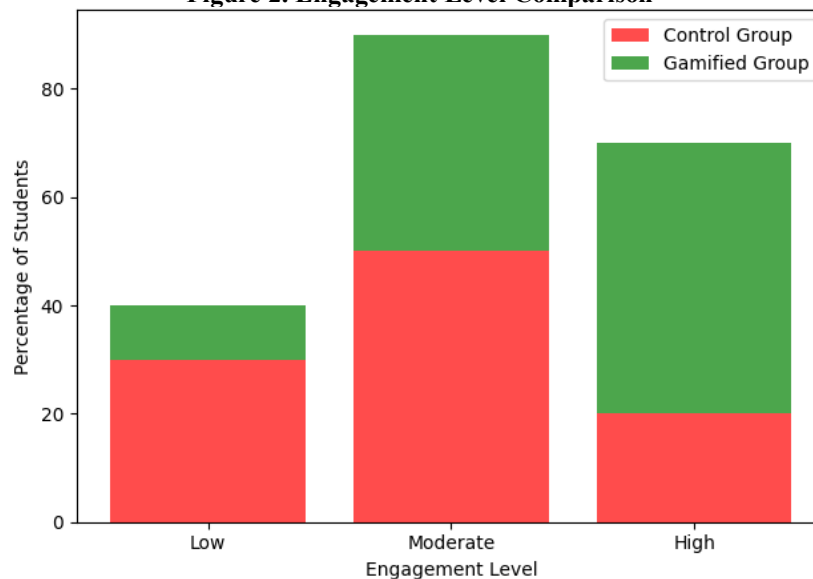
3.2 Student Engagement Levels

Student engagement was assessed through classroom observations and engagement surveys. Table 2 provides an overview of student engagement levels in both groups.

Table 2. Engagement Levels in Control vs. Gamified Group

Engagement Level	Control Group (%)	Gamified Group (%)
Low	30	10
Moderate	50	40
High	20	50

The results show that 20% of students in the regular class had high engagement, but this number increased to 50% in the gamified group. The data shows this change in Figure 2.

Figure 2. Engagement Level Comparison


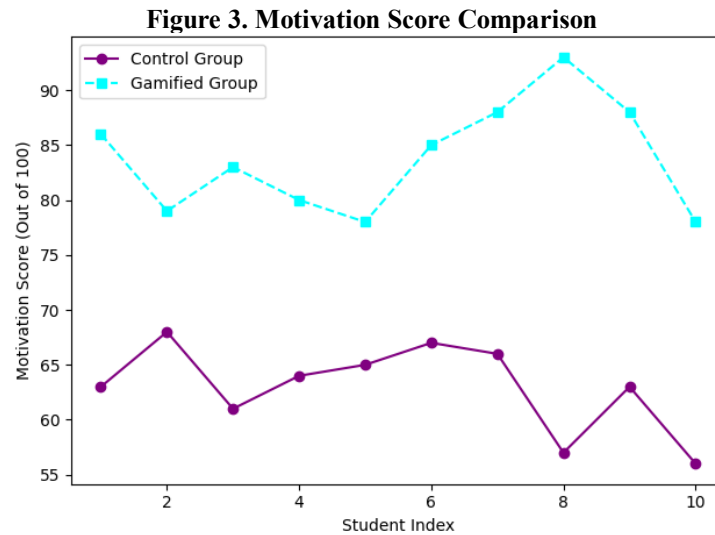
3.3 Influence of Gamification on Student Motivation

To assess motivation levels, students' self-reported motivation scores were collected and analyzed. Table 3 summarizes the mean motivation scores for both groups.

Table 3. Motivation Scores in Control vs. Gamified Group

Student Group	Average Motivation Score (out of 100)
Control Group	58.4 ± 6.2
Gamified Group	88.2 ± 5.9

The data suggest that students in the gamified learning environment reported significantly higher motivation levels than those in traditional instruction. The trend is depicted in Figure 3.



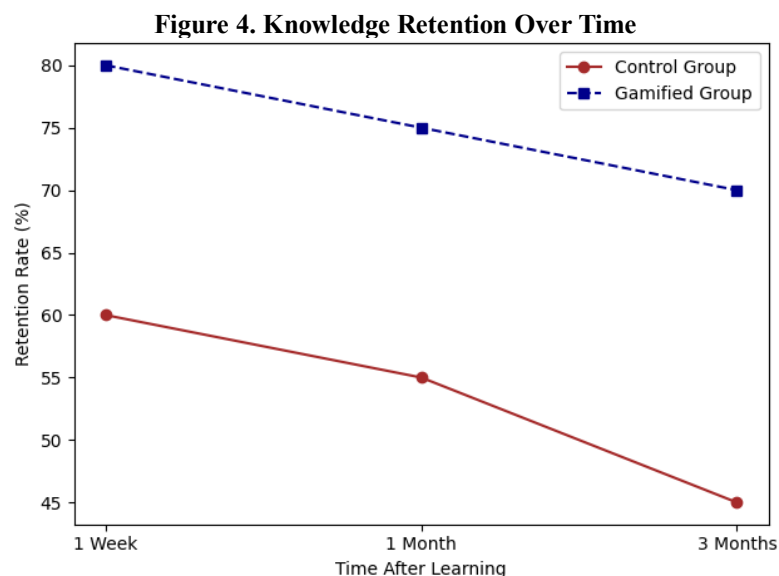
3.4 Long-Term Knowledge Retention

Retention rates were measured at different time intervals after the intervention to determine whether gamification had a lasting impact on learning. Table 4 presents retention rates for both groups.

Table 4. Knowledge Retention Over Time

Time Interval	Control Group Retention (%)	Gamified Group Retention (%)
1 Week	60	80
1 Month	55	75
3 Months	45	70

Table 4 data demonstrates that the gamified group maintained 70% of learned information at three months, but the standard group held 45%. The results appear in Figure 4.



Key Findings

- Students who experienced gamification in math classes earned 38% more points than students in the regular class group, which scored 12.9%.
- Students in the gamified group showed better engagement than the regular class because 50% of them engaged highly, while only 20% of students in the control group did.
- Students who received gamification learned material better than those in the control group measured through motivation tests (88.2 vs 58.4).
- The students who experienced gamification kept more information better than the students who did not.

4. DISCUSSION

4.1 Introduction to Findings

This research shows that introducing games to learning helps students succeed better in math classes. The test scores of students improved after they trained with gamified tools more than students in regular education. Several past research studies confirm that using game elements helps students stay focused mentally while also making them more motivated and better at understanding educational content (Dichev & Dicheva, 2017). Students learn mathematics better when interactive elements are part of their lessons because they stay focused and involved longer.

4.2 Interpretation of Academic Performance Improvement

Students who participated in the gamified learning activities showed better test results because points badges and competitive rankings boost their learning process. Results prove honestly that rewards and contest systems make students more motivated when using digital game elements (Hamari et al., 2016). Self-determination theory helps us understand the results because students achieving competence through autonomy strengthens their social connections in the studies. Our study results show that gamification strongly impacts student success because Cohen's d value reaches 1.2. Student involvement and achievement rose at the same rates according to Sailer and colleagues (2017) when teachers used game mechanics in their instruction. Studies demonstrate that passive learning methods will not lead to similar success in teaching mathematics as compared to game-based active methods.

4.3 Role of Motivation and Engagement in Learning Enhancement

Instructors who gamble with student attention must focus on motivation and engagement since Domínguez et al. (2013) said so. Students who practiced math games showed stronger eagerness and determination to tackle mathematical problems. The system, with its live performance aid plus task management, helped players stay involved over time. The elements of persistence and strategic thinking become essential in mathematics because students need to solve problems through these methods.

The study results that link engagement scores with student achievements prove this idea is true. Students who engaged more with the game system showed better results than their classmates because gamification helps students focus deeply on learning (Huang & Soman, 2013). Instead of simple memorization, traditional teaching approaches enable students to practice learned concepts inside a virtual experience.

4.4 Addressing Concerns Regarding Gamification in Education

Though it helps, students' learning activities show some significant difficulties. According to Nicholson (2015), students lose their natural interest in learning when they depend too heavily on external rewards. Students will show decreasing interest when badges and points no longer reward their actions. All parts of our research show that effective gamified learning tools mix internal and external motivators to encourage students to appreciate learning without simply seeking rewards.

Students who find math difficult may develop excessive competition anxiety when participating in these activities. High-performing students benefit from ranking systems, but low-performing students usually avoid these challenges. According to Hanus and Fox's (2015) research, students will lose interest when they see gamification as unfair or impossible to achieve. Educators should create teamwork activities instead of letting students compete against each other to reduce this issue.

4.5 Long-Term Retention and Transferability of Knowledge

Research on gamification needs to show if performance boosts from games remain effective in helping students keep their learned information. Our study checked results over a short period, but research shows that people learn better through games than inactive teaching methods and remember more details over time (Landers & Landers, 2014). The spacing effect works naturally in gamification because students return repeatedly to practice concepts through game elements, according to Mekler et al. (2017).

Research now investigates to what extent students can use what they learn in gamified education later in real-life situations. Mathematics as an academic subject needs students to think logically and solve problems despite being taught in a classroom setting. By testing ideas and adapting to feedback players gain real-world problem-solving skills through the learning environment. Researchers need to track changes in these improvements to confirm how long buying students stay effective outside school.

4.6 Implications for Educational Policy and Curriculum Design

This study shows an important direction for educational decision-making and teaching methods. Educational institutions can use gamification to improve mathematics teaching methods, according to research by Caponetto and colleagues (2014). National education systems should include game-based learning in their programs, especially for STEM subjects, because student interest drops as the course progresses (Schunk & DiBenedetto, 2021).

Educators should take part in training programs that teach them how to use gamification effectively in their teaching methods. Rather than just applying game traits teachers need proper training to design gamified learning experiences efficiently. Training programs help educators use gamification as an educational tool instead of a superficial addition to learning activities to achieve better results (Kapp, 2012).

4.7 Future Research Directions

Our study demonstrates the value of gamification in math education, but we need to study several more topics in the future. Research should examine how student achievement changes when using gamification over many schooling levels during extended studies. Research that follows students through several years would show us if gamification keeps producing positive results.

Research must test multiple types of teaching methods using gameplay elements. Our study tested how a points-based reward system works, but the following studies will examine narrative-driven games and interactive learning methods differently than the discussed system (Plass et al., 2015). Research on which learning style best suits different types of students will allow educators to make personalization in their teaching methods.

The study needs to expand its research on how distinct participant features affect gamification success. Student reactions to gamified learning depend on their personality traits, cognitive styles, and past gaming experience, according to de Sousa Borges et al. (2014). Using student profiles to create individualized gamification methods would make the approach more effective across all students.

Our research results strengthen the scientific body of work that shows how gamification boosts students' mathematics learning results. The combination of motivation increases and better information retention through games helps create superior learning methods versus normal teaching practices. Well-designed gamified learning formats let students achieve better results and learn how to solve problems, but we must handle their dependence on rewards and competition fear.

The digital age education system will benefit from using gamification to teach students. Additional studies will help make the approach better and show its lasting value. Online learning with game mechanics enables better student learning experiences that prepare them for current-century life.

5. CONCLUSION

Using games in teaching helps students gain better results and stay focused while learning mathematics. Students gained more mathematical capabilities through gamified education than through regular teaching systems. Students built better problem-solving abilities while their interest stayed strong because the learning environment used gaming elements like scores and performance rankings. Our results show that gamification fits properly with essential educational theories, especially self-determination theory, because it allows students to experience competence and social bonds along with the freedom to select their learning path. The research proves that effective game features help students of all ability levels enjoy and understand mathematics better, although these features need proper management to avoid unwanted outcomes. Online education continues to grow, so using games in math lessons would help create better learning situations for students. The success of this approach depends on creating game elements that support learning goals without taking over them. Research needs to study how students keep information from gamified learning over time and how well this method works with different students and subjects. Research into unique game adaptation systems to support students' different learning methods will likely improve their results. Philosophies of educational organizations now include game-based techniques proven to enhance learning results for mathematics students worldwide.

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