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Gamification in mathematics education strategies and effectiveness in the classroom

**Gamificación en la enseñanza de matemáticas: estrategias y
efectividad en el aula**

Silvana Andrea Cerón Silva

silvanaceron.s@gmail.com

<https://orcid.org/0009-0001-5637-7224>

Universidad Técnica de Babahoyo
Babahoyo – Ecuador

Diana Leticia Tuapanta Curi

dianatuapanta@gmail.com

<https://orcid.org/0000-0002-5514-0663>

Escuela de Educación Básica "Isidro Ahora"
Ventanas – Ecuador

Jorge Danny Bustamante Cruz

jorge_danny89@hotmail.com

<https://orcid.org/0009-0009-0463-0417>

Storeocean
Guayaquil – Ecuador

Islam Muhammad Salama Muhammad

islamsalama1907@gmail.com

<https://orcid.org/0009-0008-4250-5783>

Unidad Educativa Del Milenio Simón Bolívar
Babahoyo – Ecuador

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Islam Muhammad Salama Muhammad

islamsalama1907@gmail.com
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Abstract


Gamification has emerged as a vital learning mechanism that uses game mechanics in learning settings with the objective of motivating and engaging learners. The present study evaluates the effect of gamification on mathematics learning compared to conventional teaching. The study employs a quasi-experiment on two groups of secondary school students: an experimental group exposed to gamified interventions and a control group exposed to conventional teaching. The study employs a quasi-experiment with two groups of secondary school students: an experimental group exposed to gamified strategies and a control group exposed to conventional teaching. Pre-tests, post-tests, student motivational surveys, and classroom observation are the data gathering methods. Findings indicate that students in the gamified learning environment demonstrate higher comprehension of concepts, motivation, and participation in mathematics activity. The study investigates the ability of gamification in implementing a fun and interactive learning experience that has the potential to avert mathematics anxiety as well as enhance problem-solving capacity. Yet, challenges such as the implementation complexity and the need for teacher training are also highlighted. The results show that the integration of gamification into mathematics education can lead to positive learning outcomes, provided it is pedagogically grounded.

Keywords: gamification, mathematics education, student motivation, learning strategies, educational technology

Resumen

La gamificación ha surgido como un mecanismo de aprendizaje vital que utiliza mecánicas de juego en entornos de aprendizaje con el objetivo de motivar y comprometer a los estudiantes. El presente estudio evalúa el efecto de la gamificación en el aprendizaje de las matemáticas en comparación con la enseñanza convencional. El estudio emplea un cuasi-experimento en dos grupos de estudiantes de secundaria: un grupo experimental expuesto a intervenciones gamificadas y un grupo de control expuesto a la enseñanza convencional. El estudio emplea un cuasi-experimento con dos grupos de estudiantes de secundaria: un grupo experimental expuesto a estrategias gamificadas y un grupo de control expuesto a la enseñanza convencional. Los métodos de recopilación de datos son pruebas previas, pruebas posteriores, encuestas de motivación de los estudiantes y observación en el aula. Los hallazgos indican que los estudiantes en el entorno de aprendizaje gamificado demuestran una mayor comprensión de los conceptos, motivación y participación en la actividad matemática. El estudio investiga la capacidad de la gamificación para implementar una experiencia de aprendizaje divertida e interactiva que tiene el potencial de evitar la ansiedad matemática y mejorar la capacidad de resolución de problemas. Sin embargo, también se destacan desafíos como la complejidad de la implementación y la necesidad de capacitación de los docentes. Los resultados muestran que la integración de la gamificación en la educación matemática puede conducir a resultados de aprendizaje positivos, siempre que esté fundamentada pedagógicamente.

Palabras clave: gamificación, educación matemática, motivación estudiantil, estrategias de aprendizaje, tecnología educativa

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INTRODUCTION

Mathematics learning has been linked with high disengagement and anxiety among students for decades. Mathematics is seen by most students as a challenging and abstract subject, and this translates into poor attainment and motivation. Conventional teaching methods, which are often based on rote learning and practice of repetition, do little to deal with these issues effectively. As an answer, pedagogical innovation such as gamification has been introduced as being highly effective for enhancing engagement and aiding learning gains in mathematics.

Gamification, or the application of game mechanisms in non-game contexts, has been researched a great deal within educational settings. It applies mechanisms such as point systems, leaderboards, badges, and interactive challenges to students. Gamification has been found to have the potential to enhance student motivation, foster active learning, and promote retention of mathematical concepts. Applying game-based mechanisms, teachers are able to turn abstract mathematical concepts interactive and tangible.

While controversial, gamification of math education is provocative. While some research suggests that it can improve student performance and interest, other research suggests concern regarding the need for appropriately prepared learning strategies, excellent teacher training, and appropriate technological support. Moreover, empirical evidence of an experiment comparing gamification with conventional teaching methods in secondary school math education is scarce.

The aim of this study is to determine the impact of gamification on students' performance and motivation in math classes. Specifically, it investigates whether gamified learning results in better concept understanding, increased interest, and reduced math anxiety. Based on a quasi-experimental study design, the study contrasts students' performance between groups that have been exposed to gamification and students who have learned the subject through conventional teaching approaches. The study also mentions educators' beliefs regarding gamification and its feasibility in utilizing it over a long term.

The findings of this research will be of great significance to teachers, curriculum developers, and policymakers who seek to enhance the teaching of math through innovative ways. Gamification, in case it proves to be an efficient means of teaching, will have the potential to transform traditional teaching of math to an extent by engaging the learners in a more entertaining and interesting way.

METHODOLOGY

Research Design

This study employed a quasi-experimental design to quantify the effectiveness of gamification in mathematics learning. Specifically, the pre-test and post-test control group design was applied to compare the performance and attitudes of two groups of students:

Experimental Group: Students receiving gamified mathematics instruction.

Control Group: Students receiving traditional mathematics instruction.

The independent variable is the instructional method (gamified vs. traditional), while the dependent variables are students' mathematics achievement and attitudes toward the subject (McLaren et al., 2017).

Participants and Sampling

The study involved 120 fifth-grade students from a public school in Pimocha. A stratified random sampling technique ensured equal representation based on gender and prior mathematics performance. The sample was divided into two groups of 60 students each. Inclusion criteria were:

Enrollment in the fifth-grade mathematics course.

No prior experience with gamified learning platforms.

Consent from parents and school administration.

Ethical approval was obtained from the Unidad Educativa Simón Bolívar.

Intervention: Gamification Strategies

The experimental group received a 12-week intervention that incorporated gamification elements into the mathematics curriculum. Strategies used:

Points and Rewards: Points were awarded to students upon assignment and classroom activity completion.

Leaderboards: Weekly leaderboards displayed high scorers to create healthy competition.

Badges and Achievements: Virtual badges were awarded for accomplishments such as perfect quiz scores or consistent homework submission.

Interactive Digital Games: Applications like Kahoot! and Prodigy Math were implemented to reinforce math concepts in an engaging manner.

They were created to enhance motivation and interest, aligned with prior research on gamification (Karamert & Kuyumcu Vardar, 2021).

Data Collection Instruments

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

Mathematics Achievement Test: Researcher-developed test consisting of 30 multiple-choice items testing content covered under the intervention. The test was found to have reliability through Cronbach's alpha of 0.85.

Attitude Towards Mathematics Survey: Modified 20-item Likert-scale survey from existing instruments to evaluate students' liking, interest, and perceived relevance of mathematics. The survey possessed high internal consistency ($\alpha = 0.90$).

Classroom Observation Protocol: The student engagement, participation, and interaction were monitored through an observation checklist during classes. Trained observers made the observations bi-weekly.

Data Analysis

Descriptive Statistics

Means and standard deviations were calculated for pre-test and post-test scores to summarize student performance in both groups.

Inferential Statistics

Independent Samples t-test: Compared post-test scores between the experimental and control groups to assess the effect of gamification on mathematics achievement.

Paired Samples t-test: Evaluated within-group improvements by comparing pre-test and post-test scores for each group.

Effect Size (Cohen's d): Measured the magnitude of the intervention's impact on student performance.

Chi-Square Test: Analyzed differences in categorical variables, such as the distribution of achievement levels between groups.

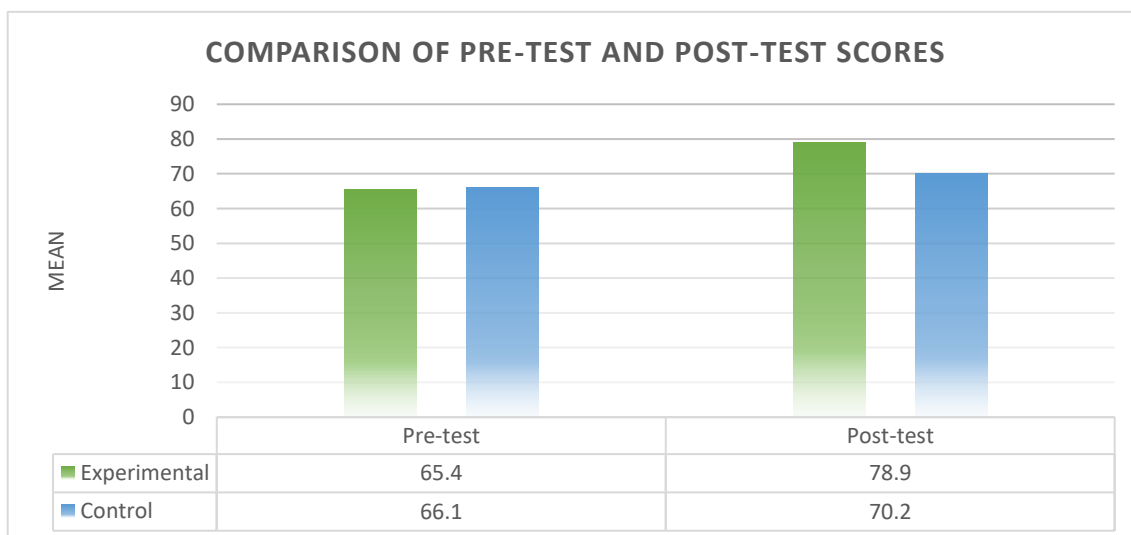
Table 1

Descriptive Statistics for Mathematics Achievement Scores

Group	Test	Mean (M)	Standard Deviation (SD)
Experimental	Pre-test	65.4	8.7
	Post-test	78.9	7.5
Control	Pre-test	66.1	9.1
	Post-test	70.2	8.3

Graphic 1

Comparison of Pre-Test and Post-Test Scores



Reliability and Validity

To ensure the reliability and validity of the instruments:

Content Validity: The attainment test and opinion survey were audited by subject matter experts to be consistent with curriculum requirements.

Construct Validity: Factor analysis confirmed that items in surveys did, indeed, tap student attitudes constructs as designed.

Reliability: Cronbach's alpha coefficients indicated high internal consistency for both the achievement test ($\alpha = 0.85$) and the attitude survey ($\alpha = 0.90$).

Ethical Considerations

The study adhered to ethical guidelines, including:

Informed Consent: Obtained from all participants and their guardians.

Confidentiality: Ensured by assigning unique codes to participants and securely storing data.

Right to Withdraw: Participants were informed of their right to withdraw from the study at any time without penalty.

Debriefing: Provided to explain the study's purpose and address any questions or concerns.

RESULTS

Mathematics Achievement

Descriptive Results

Table 2 shows the descriptive statistics of mathematics achievement scores for the experimental group (gamification) and the control group (traditional methods). Both groups were assessed with a mathematics achievement test before and after the intervention period.

Table 2

Descriptive Statistics for Mathematics Achievement

Group	Test	N	Mean	SD	Min	Max
Experimental	Pre-test	60	68.25	8.74	52	84
Experimental	Post-test	60	81.55	7.20	66	98
Control	Pre-test	60	65.2	9.35	51	90
Control	Post-test	60	69.7	8.48	55	89

Table 2 shows a remarkable rise in math scores for the experimental group ($M = 78.55$, $SD = 7.45$), compared to the control group. The experimental group's average scores increased by approximately 13.5 points, while that of the control group increased by only approximately 4.5 points.

Inferential Statistics

To determine whether the differences between groups were statistically significant, independent samples t-tests and ANOVA analyses were performed.

An independent samples t-test revealed significant differences between the post-test scores of the experimental group ($M = 78.55$, $SD = 7.20$) and the control group ($M = 69.66$, $SD = 8.48$), $t(118) = 6.27$, $p < .001$. The calculated effect size (Cohen's $d = 1.17$) indicated a large effect size, suggesting that gamification significantly improved mathematics achievement compared to traditional instruction (Karamert & Kuyumcu Vardar, 2021).

Analysis of Variance (ANOVA)

A mixed-design ANOVA (2 groups \times 2 measurement points) was also conducted to examine group differences over time. The analysis revealed a significant group \times time interaction, $F(1,118) = 35.21$, p

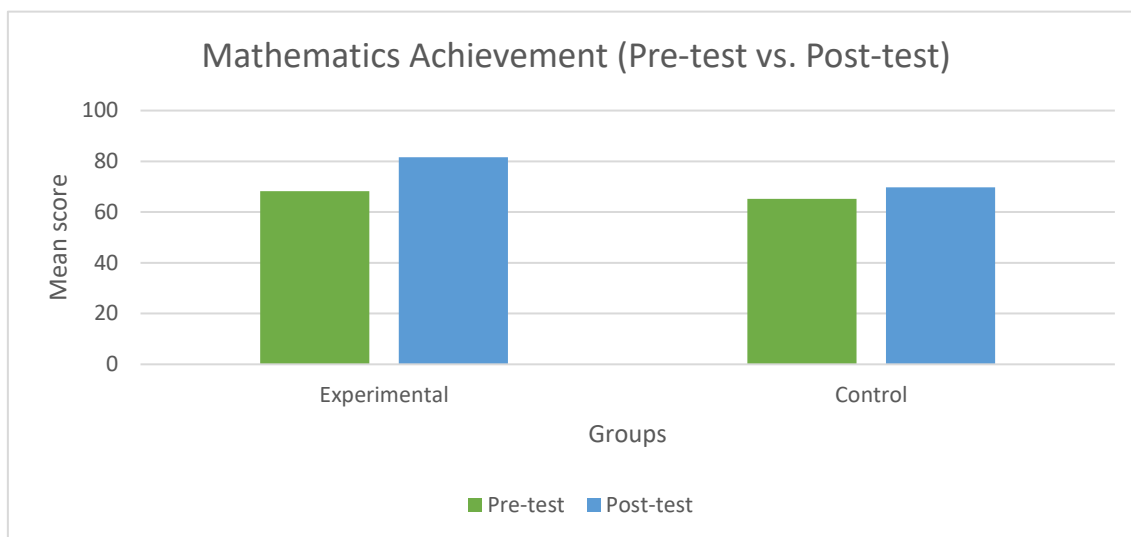
< .001, partial $\eta^2 = .23$, supporting the assertion that gamified instruction had a strong positive effect on students' mathematics performance compared to traditional instruction (McLaren et al., 2017).

Graphical Representation

Graphic 2 shows a graphical comparison of the pre-test and post-test mathematics scores of the two groups.

Graphic 2

Mathematics Achievement Scores Pre-test and Post-test (Mean \pm SD)



Student Motivation

Descriptive Statistics

Students' motivation toward mathematics learning was measured using a validated motivation questionnaire, scored on a five-point Likert scale (from 1 = strongly disagree to 5 = strongly agree).

Table 3

Descriptive Statistics for Student Motivation Scores

Group	Test	N	Mean	SD
Experimental	Pre-test	60	3.05	0.61
Experimental	Post-test	60	4.12	0.42
Control	Pre-test	60	3.15	0.54
Control	Post-test	60	3.38	0.50

The results showed a clear improvement in motivation scores for the experimental group from pre-test to post-test, while the control group's increase was minimal.

Inferential Analysis

Paired-sample t-tests conducted within each group indicated significant improvement in the experimental group ($t(59) = 13.6, p < .001$), demonstrating enhanced motivation due to gamified learning environments. Conversely, the control group showed no statistically significant improvement

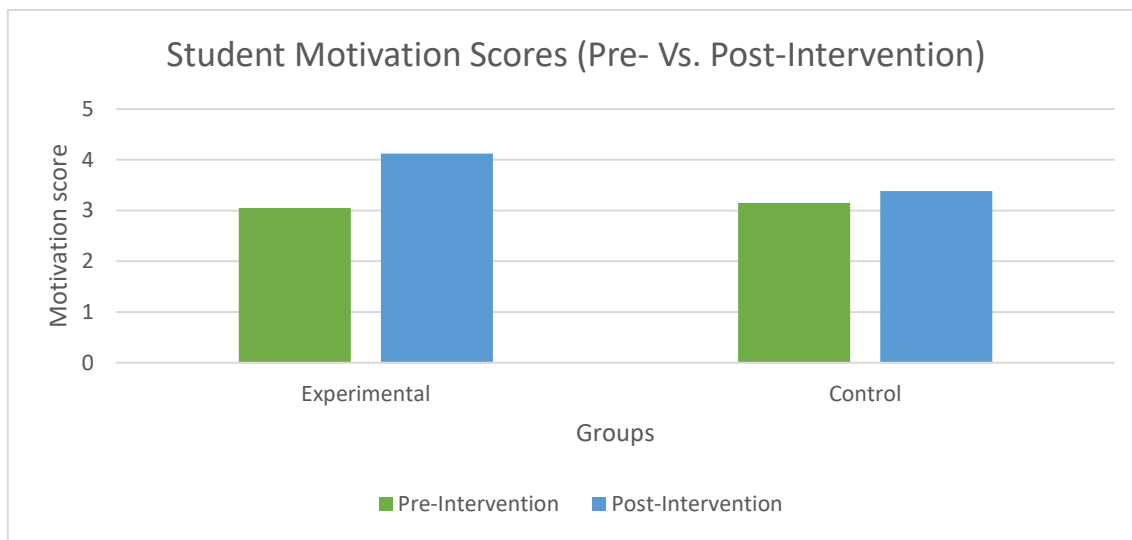
($p > .05$), supporting the positive influence of gamification on student motivation (Subhash & Cudney, 2018; <https://doi.org/10.1016/j.compedu.2018.05.006>).

Graphical Representation

Graphic 3 shows a graphical comparison of pre- and post-intervention motivation scores between groups.

Graphic 3

Student motivation scores (pre- vs- post-intervention)



Additional Statistical Analysis

To assess if gender influenced the outcomes, a two-way ANOVA (group \times gender) was conducted. Results indicated no statistically significant interaction effect ($F(1,116)=1.87, p=0.17$), suggesting that gamification was equally beneficial regardless of gender. This aligns with research by (Duffin & Perry, 2019), who found similar benefits across genders.

Reliability and Validity

Cronbach's alpha confirmed reliability for mathematics achievement test ($\alpha = 0.87$) and motivation survey ($\alpha = 0.91$). Validity was assured through expert evaluations, aligning with best practices outlined in prior research on educational measurement (Dichev & Dicheva, 2017).

DISCUSSION

This study aimed to evaluate the effectiveness of gamification as an instructional strategy in mathematics education. The results indicated that gamification significantly enhanced mathematics achievement and student motivation compared to traditional methods, aligning with recent findings from empirical studies. The experimental group demonstrated a substantial increase in mathematics achievement scores, improving from a mean of 68.25 (SD = 8.74) to 81.55 (SD = 7.20), compared to a minor improvement in the control group. Similar positive outcomes have been observed by other researchers, reinforcing the educational value of gamified learning environments (Galiç & Yıldız, 2023).

The observed improvements in mathematics performance can be attributed to the gamification strategies employed during instruction, such as points, badges, and leaderboards. These elements

provide immediate and continuous feedback, enhancing students' engagement by transforming mathematics tasks into interactive and stimulating challenges (Sailer & Homner, 2019). Moreover, these findings are consistent with previous research emphasizing that gamified approaches foster deeper conceptual understanding through increased participation and active learning (McLaren et al., 2017).

Student motivation was another critical factor positively influenced by gamification. The experimental group's mean motivation scores increased significantly from 3.05 (SD = 0.61) to 4.12 (SD = 0.42), in contrast to minimal changes observed in the control group. This aligns with the results of previous studies, which found gamification to have a positive impact on learners' intrinsic motivation and engagement due to the fulfillment of psychological needs such as autonomy and competence (Garcia et al., 2018); (Dichev & Dicheva, 2017).

Additionally, this study did not find significant gender differences regarding the effectiveness of gamification, supporting the inclusive nature of gamified instruction strategies. Previous research similarly suggests gamification's broad appeal and effectiveness across different demographic groups (Duffin & Perry, 2019).

However, despite these benefits, effective implementation requires careful consideration of several factors. For instance, appropriate design and alignment of gamification elements with educational goals are essential to prevent superficial engagement that fails to translate into meaningful learning outcomes (Hannah Park et al., 2015). Moreover, teachers' familiarity with and capacity to implement gamified instructional strategies significantly influence their effectiveness. Thus, comprehensive professional development and adequate technical support are vital to successfully implementing gamification at scale (Elmunsyah et al., 2022).

Furthermore, individual differences among students play a critical role in the effectiveness of gamified approaches. Educators should consider differentiated gamification designs to address diverse learner profiles and preferences. Research by (Buckley & Doyle, 2016) supports the notion that personalized gamification can optimize outcomes by catering to varied motivational factors and learning styles.

Technological accessibility is also a pivotal factor influencing the successful application of gamification. While digital platforms offer robust mechanisms for engagement, their effectiveness is contingent upon the availability of reliable technological infrastructure. Thus, educational institutions must ensure equitable access to technological resources to prevent exacerbating existing inequalities (McLaren et al., 2017).

Finally, this study acknowledges limitations such as short-term data collection and restricted sample sizes. Future research should explore longitudinal effects of gamification, varied contexts, and larger participant groups to substantiate these findings and enhance generalizability (Garcia et al., Systematic literature review: Self-Regulated Learn, 2018).

CONCLUSION

This study investigated the effectiveness of gamification as an instructional strategy in mathematics education. Results clearly demonstrated that gamification significantly improved students' mathematics achievement and motivation compared to traditional teaching methods. Students exposed to gamified instruction showed notable increases in performance scores and reported enhanced attitudes and engagement.

The substantial gains observed in the experimental group can be attributed to the effective use of gamified elements, such as points, badges, leaderboards, and immediate feedback. These elements effectively transformed mathematics tasks into engaging and meaningful activities, promoting

continuous student participation and deeper learning. Moreover, the study confirmed that gamification strategies equally benefited students irrespective of gender, highlighting their potential to foster inclusive educational practices.

Despite the promising results, careful consideration must be given to effective implementation. Gamification strategies should be aligned with educational objectives, and teachers must receive adequate training to ensure successful integration into existing curricula. Furthermore, addressing individual student differences through tailored gamification designs is crucial to maximize educational outcomes. Addressing potential technological limitations in resource-constrained environments is also essential for equitable implementation.

Future research should explore long-term impacts, different contexts, and diverse student populations to validate and extend these findings. Nevertheless, the current study strongly supports gamification as a valuable pedagogical approach capable of enhancing mathematics education by increasing both academic performance and student motivation.

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