Enhancing Grade 7 Students' Understanding of Prime Factorization and GCD Concepts through Gamification

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DOI: https://dx.doi.org/10.47772/IJRISS.2025.907000108

Received: 23 June 2025; Accepted: 27 June 2025; Published: 01 August 2025

ABSTRACT

This study explored the effectiveness of gamified instruction in enhancing Grade 7 students' understanding of Prime Factorization and the Greatest Common Divisor (GCD). Using a quasi-experimental one-group pre-test–post-test design, the research involved 50 students from a public junior high school in Luzon, Philippines. The intervention integrated gamification elements—such as points, badges, and rewards—into daily remedial lessons over a two-week period. Pre- and post-tests consisting of 20 items were administered to measure student performance before and after the intervention.

Results showed a significant improvement in students' understanding of the prime factorization and GCD concepts based on the pre-test and post-test scores, with the mean increasing from 5.60 during the pre-test to 12.02 and large effect size ($r = 0.84$), indicating the positive impact of gamification on student learning. Additionally, the reduction in standard deviation suggests more consistent performance across the students. Statistical analysis using the Wilcoxon Signed-Rank Test confirmed that the improvement was highly significant ($p < 0.001$).

The findings support existing literature on gamified learning environments' motivational and cognitive benefits. However, the study also acknowledges the importance of strategic and balanced implementation, as overuse or misapplication may reduce effectiveness. The research recommends broader application with larger, more diverse samples and longer intervention periods. Gamification, when thoughtfully applied, can serve as a powerful tool to increase engagement, boost confidence, and improve mastery of foundational mathematical concepts.

Keywords: Gamification, Prime Factorization, Greatest Common Divisor, Learning Mathematics

INTRODUCTION

Mathematics is widely regarded as one of the most challenging subjects in the academic curriculum. Its abstract nature and cumulative structure often cause students to struggle with conceptual understanding and procedural fluency (Zaharin, 2021). Despite these challenges, mathematics remains essential in developing higher-order thinking, logical reasoning, and problem-solving skills critical for success in academic and real-life contexts (Cholily, 2018; Fadlelmula, 2022). Mathematics instruction fosters analytical thinking, enhances creativity, and cultivates precision and discipline—indispensable in today's knowledge-driven society.

At the foundational level, mathematics builds cognitive structures necessary for tackling more complex disciplines such as algebra, geometry, and data science. Foundational topics such as prime factorization and the greatest common divisor (GCD) serve as crucial stepping stones for understanding more advanced mathematical operations such as simplifying fractions, manipulating radicals, and solving real-life problems. Despite their fundamental importance, Filipino learners continue to face persistent difficulties in mastering these concepts (Valderama & Oligo, 2021). These challenges are compounded by the high rate of forgetting previously learned mathematical ideas, especially those taught in earlier grade levels—a phenomenon observed in both public and private educational settings.

Traditional teaching methods, characterized by rote learning and teacher-centered instruction, remain

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VII July 2025

predominant in many Philippine classrooms (Akbarov, 2014; Boumova, 2008). In such settings, students are passive recipients of information, often disengaged from the learning process. However, the demands of 21st-century education call for a paradigm shift towards learner-centered approaches that promote active learning, collaboration, and contextual application of knowledge (Fitriani et al., 2020). The ability to retain and apply mathematical concepts is further challenged by gaps in instructional quality, socioeconomic disparities, and disruptions brought about by the COVID-19 pandemic, which forced an abrupt transition from face-to-face to remote learning modalities (Sapin, 2023).

The gravity of these learning gaps is evident in international assessments. According to the 2019 Trends in International Mathematics and Science Study (TIMSS), the Philippines ranked lowest among participating countries in mathematics and science, scoring an average of 297 points—well below the international mean (Sapin, 2023; Nob et al., 2024). Similarly, the 2022 Programme for International Student Assessment (PISA) placed the Philippines 76th in mathematics and reading and 79th in science out of 81 countries (Data Pandas, 2025). These results not only highlight systemic issues in basic education but also underscore the urgent need for innovative and engaging teaching strategies that can bridge the gap between instruction and long-term conceptual understanding.

One such strategy gaining international attention is gamification—the integration of game elements such as points, levels, and rewards into non-game contexts like education (Khoshnoodifar, 2023). Research suggests that gamification can improve motivation, engagement, and academic performance by making learning more interactive and enjoyable (Mezeiová, 2021; Sezgin & Ozdemir, 2021). In particular, gamified instruction has shown promise in enhancing mathematical fluency and problem-solving skills among elementary students (Varela et al., 2021; Cunha et al., 2018). These studies consistently indicate that gamification is most effective when it promotes active participation, timely feedback, and a sense of achievement among learners.

While most gamification research has focused on primary education, its application in secondary school settings remains underexplored, especially at the transition point from elementary to junior high school mathematics classrooms. Grade 7 students, in particular, often experience significant academic and emotional adjustments as they shift to a more demanding learning environment (Cornillez et al., 2021). This transitional period is critical for establishing strong learning habits and mathematical foundations. At this stage, gamification can ease the shift, rekindle interest in math, and improve conceptual retention.

Recent studies have pointed to specific misconceptions among students about prime numbers and factorization. For example, Sutarto et al. (2021) found that nearly half of the surveyed students mistakenly categorized prime numbers as composite, indicating conceptual confusion often rooted in earlier instruction. Addressing these misunderstandings through gamified instruction could offer a novel way to correct misconceptions while increasing engagement and long-term retention.

In this context, the present study seeks to explore the effectiveness of gamification in improving Grade 7 students' understanding of prime factorization and the greatest common divisor. By involving students actively in their learning process through game-based instructional design, the research aims to assess whether gamified strategies can significantly enhance student performance and concept retention in foundational mathematics.

This study aims to assess the effectiveness of gamification in improving student understanding and retention of the mathematical concepts of prime factorization and the greatest common divisor (GCD) among Grade 7 students.

Specifically, it seeks to answer the following questions:

1. How knowledgeable are the students in prime factorization and greatest common divisor before implementing gamification?
2. How was the performance of the students based on the post-test results after implementing gamification?
3. Is there a significant improvement between the pre-test and post-test scores of students after gamified instruction?

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue VII July 2025

METHODOLOGY

This study aimed to evaluate the effectiveness of gamification in enhancing Grade 7 students' understanding of *Prime Factorization* and the *Greatest Common Divisor (GCD)*. A quasi-experimental research design, specifically a one-group pre-test post-test design, was employed. This design allows for the assessment of changes in student performance before and after an instructional intervention without the use of a control group. As noted by Stratton (2019), such designs are especially useful in educational settings where random assignment is not feasible, yet the researcher still seeks to evaluate the impact of an intervention.

The study was conducted with one intact class of Grade 7 students from a public junior high school located in Luzon, Philippines. The sample was selected based on availability and existing school structure. The group was chosen due to their accessibility and the appropriateness of their curriculum content in relation to the topics under investigation.

To assess students' knowledge, the researcher developed a 20-item teacher-made test comprising 10 questions on Prime Factorization and 10 questions on GCD. The test was validated for content and clarity by both the researcher and a subject matter expert in mathematics. This same instrument served as both the pre-test and post-test, allowing for a direct comparison of student performance before and after the intervention.

The gamified instructional intervention was integrated into the class's 20-minute daily remedial session over two weeks, excluding Fridays. This time slot was selected to minimize interference with core instruction and to maintain student engagement. According to Maldonado (2021), short, consistent instructional periods offer students time to process content more effectively and reduce academic fatigue.

During these sessions, the teacher-researcher implemented the gamification strategies where the use of points, badges, and symbolic rewards such as recitation chips were integrated into the classroom activities. These rewards served as incentives for correct answers and encouraged active participation. Prior research supports the effectiveness of such reward systems in improving mathematics performance and fostering engagement (Inandan, 2020).

On the first day, students were briefed about the intervention and took the pre-test. Due to time constraints, students were given an extension to complete the test the following day. This was aligned with the recommendations of Gernsbacher (2015), who argued that students often benefit from extended time to reduce anxiety and improve test validity. Gernsbacher et al. (2020) also emphasized that time-limited assessments can compromise test reliability, inclusivity, and equity—further supporting the decision to provide sufficient time for completion.

Over the next days, instruction on Prime Factorization was delivered, beginning with a conceptual discussion and followed by practice exercises. Students who answered questions correctly received gamified rewards. In the second week, the same instructional sequence was applied to the topic of the Greatest Common Divisor (GCD). Throughout both phases, formative assessment and immediate feedback were integral to the learning process, ensuring ongoing student participation and motivation.

After the intervention, the participants take the post-test which aims to to evaluate their learning gains. Student scores from the pre-test and post-test were compared to determine the effectiveness of the gamified instruction.

Quantitative data were analyzed using descriptive statistics, including mean, percentage, and standard deviation, to summarize students' performance. The Shapiro–Wilk test was conducted to assess the normality of the distribution. Results ($p = .039$) indicated that the data were not normally distributed. Consequently, the Wilcoxon Signed-Rank Test, a nonparametric statistical test, was used to determine if the difference between the pre-test and post-test scores as statistically significant.

Additionally, effect size calculations were conducted to assess the magnitude of the instructional intervention's impact. As Maher, Markey, and Ebert-May (2013), effect size shows the practical relevance or intensity of the association between variables, whereas statistical significance shows whether an observed effect is likely the result of chance.

RESULTS AND DISCUSSION

Students' Understanding of Prime factorization and Greatest Common Divisor Concepts

Table 1: Comparison of the pre- and post-test results of Prime Factorization and Greatest Common Divisor

Content	**Pre-Test**		**Post Test**	
	Mean	Standard Deviation	Mean	Standard Deviation
Prime Factorization	2.44	1.49	5.92	1.61
Greatest Common Divisor (GCD)	3.16	2.76	6.1	2.03

Table 1 presents the comparison of pre-test and post-test scores of Grade 7 students in Prime Factorization and Greatest Common Divisor (GCD). In the ppre-test students scored a mean of 2.44 (SD = 1.49) in Prime Factorization and 3.16 (SD = 2.76) in GCD out of a total possible score of 10. These low mean scores indicate a limited understanding of the fundamental concepts prior to the intervention. Only about 28.1% of the test items were answered correctly by students on average, showing significant conceptual gaps.

After the gamification-based intervention, the post-test results show a substantial improvement, with the mean scores increasing to 5.92 (SD = 1.61) for Prime Factorization and 6.10 (SD = 2.03) for GCD. This corresponds to an average of 55.5% correct answers, nearly doubling the accuracy from the ppre-test These findings are consistent with Ardianto and Ariyani (2022), who found that improvements in mean scores and an increase in the dispersion (slightly higher SD) indicate active learning and engagement among participants. The improvement aligns with Khashi'ie et al. (2017), who emphasized that active learning strategies—especially those incorporating student interaction—positively impact conceptual acquisition and retention in mathematics.

Overall Performance Gain

Table 2 summarizes the overall performance comparison using combined pre-test and post-test scores (maximum score = 20). The pre-testmean of 5.60 (SD = 3.40) again highlights students' weak starting point. Post-intervention, the mean score increased significantly to 12.02 (SD = 2.53), indicating a mean gain of 6.42 points, or a 114.6% increase in overall performance. Furthermore, the standard deviation reduced by 0.87, indicating that student performance was more consistent and that scores tended to get close to the mean. This improvement indicates that students' learning gaps in prime factorization and GCD concepts may be reducing collectively as well as improving individually.

Table 2: Comparison of the performance between the Pretest and Posttest Scores

	N	Mean	Standard Deviation	Min	Max
Pre-test	50	5.60	3.40	1	15
Post-test	50	12.02	2.53	6	18

These results corroborate those of Eryılmaz and Boicu (2023), who claimed that game-based learning settings improve student precision, coherence, and engagement in the classroom. Additionally, the reduction of score variability suggests that the intervention improved classroom equity by assisting weaker students in catching up with understanding the mathematics concepts.

Table 3 presents the results of the Wilcoxon Signed-Rank Test, a non-parametric test suitable for non-normally distributed data. The test revealed a statistically significant improvement in student performance from ppre-testto post-test, with a z-score of -5.946 and p < 0.001. This result strongly supports the hypothesis that gamification positively affects students' learning outcomes.

Notably, 92% (n = 46) of students showed an increase in scores after the intervention, with a high mean rank of 26.29. Only 6% (n = 3) of students had reduced scores, and 1 student (2%) maintained the same score. The calculated effect size (r = 0.84) indicates a large and meaningful impact of the gamified instructional method on learning outcomes. This aligns with research by Li et al. (2023), which demonstrated that gamification significantly improves mathematical learning, particularly in areas requiring procedural fluency and conceptual understanding.

Table 3: Wilcoxon Signed Rank Test of Significance

Post-test – Pre-test	N	Mean Rank	Sum of Ranks	Effect size	z	p
Negative rank	3	5.17	15.50	0.84	-5.946	0.000
Positive rank	46	26.29	1209.50			
Equal Rank	1					
Total	50					

Chen and Liang (2022) emphasized that student enjoyment and self-efficacy are mediators in the effectiveness of gamified instruction. These psychological factors may explain the sharp increase in performance observed in the present study. When students feel confident and enjoy the learning process, they are more likely to engage actively and retain information.

Furthermore, Suarez (2024) highlights that gamified strategies enhance cognitive engagement and foster deeper thinking, which may have contributed to improvements in mathematical reasoning as observed in this study. The combined cognitive and affective engagement likely enhanced both surface-level understanding and higher-order thinking skills in Prime Factorization and GCD.

Implications of the Results

The strong positive outcomes of this study highlight gamification as a powerful instructional strategy for enhancing mathematics education, particularly in lower-performing settings. By integrating game elements such as points, badges, and rewards, the teacher successfully transformed routine problem-solving into engaging activities, resulting in improved retention and participation. The results are especially relevant for students in transitional academic stages (such as Grade 7), who may struggle with adapting to more complex math concepts following elementary education (Cornillez et al., 2021).

These findings support calls for a shift from traditional teacher-centered methods to more interactive, learner-centered approaches that leverage motivation and engagement as key drivers of academic success.

Results and Discussion

This study set out to evaluate the effectiveness of gamification as a pedagogical strategy in enhancing Grade 7 students' understanding of Prime Factorization and the Greatest Common Divisor (GCD). The findings showed that students' post-test scores on prime factorization and GCD concepts improved significantly when compared to their pre-test scores; the mean increase was 6.42 points, and the effect size was substantial (r = 0.84). According to these results, gamified instruction can greatly enhance student performance and mathematical concept recall. Students' understanding of complex mathematical topics has been found to be improved by the use of gamification in the classroom. The low pre-test mean scores suggest that students had limited understanding and long-term retention of the concepts, despite prior exposure in their previous mathematics classes. However, after the gamified intervention, the post-test results showed significant improvement, implying the gamified mathematics classroom's instructional effectiveness.

These findings align with those of Karamert and Vardar (2021) and Ariffin et al. (2022), who observed increased student motivation and academic achievement following gamification-based teaching. The intervention not only closed knowledge gaps but also fostered greater student confidence in tackling mathematical tasks—especially important during the transition from elementary to secondary education, a stage often marked by academic adjustment challenges (Cornillez et al., 2021).

According to these results, gamified instruction can greatly enhance student performance, engagement, and mathematical idea recall. Students' understanding of abstract mathematical topics has been found to be enhanced through the use of gamification in the classroom, which incorporates interactive features, points, badges, and symbolic prizes hoverver, coution should be observed since some studies claimed that gamified methods can result in lower long-term motivation, satisfaction, and academic results if they are overused or inadequately incorporated (Lim, 2021), and Hanus (2025) found that students in gamified courses experienced less empowerment over time and performed worse in final exams than those in traditional settings. These results suggest that gamification is not a one-size-fits-all solution and must be strategically balanced with other teaching methodologies to remain effective.

Furthermore, a number of factors, such as the classroom environment, instructor support, implementation time, and student diversity, affect how well gamification works. Future research should involve a larger and more varied set of participants, especially among Grade 7 children going through the significant transition between educational levels. It is important to keep in mind that this study only involved one class and a brief intervention time. Longer intervention durations might also yield more detailed information on mastery and retention.

RECOMMENDATIONS

1. Training and collaboration among teachers and administrators should be established to support effective integration of gamification into classroom instruction.
2. Gamified learning must be adapted to student readiness, ensuring that game elements enhance rather than distract from learning objectives.
3. Future research should explore longitudinal effects of gamification and examine how it influences not just test scores, but conceptual understanding, confidence, and long-term retention.

While gamification offers a powerful and engaging instructional alternative that can improve academic performance, its effectiveness depends also on thoughtful design, inclusivity, and sustained instructional support. When appropriately utilized, it has the potential to transform mathematics education, especially for students at critical learning junctures.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the school administrators of the participating institution for their support and assistance throughout the conduct of this study. We also extend our heartfelt gratitude to the Grade 7 students who participated in the study. Their enthusiasm, honesty, and active involvement made this research possible and meaningful.

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