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Assessing Differences in Student Motivation, Achievement, and Conceptual Understanding in a Gamified Mathematics Learning Environment

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Abstract

Although gamified learning has received growing attention in mathematics education, empirical evidence on its simultaneous influence on students' motivation, mathematics achievement, and conceptual understanding in developing educational contexts remains limited. This study examined differences in students' motivation, mathematics achievement, and conceptual understanding associated with participation in a gamified mathematics learning environment. A quasi-experimental pretest–posttest control group design was employed, involving 700 secondary school students from 15 public schools in Northeast Nigeria. Using intact classes, students were assigned to an experimental group that received curriculum-aligned gamified mathematics instruction over a four-week period or to a control group that received conventional instruction covering the same content and duration. Data were collected using pretest and posttest measures of student motivation, mathematics achievement, and conceptual understanding. Motivation was

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assessed using an adapted questionnaire with established internal consistency, while achievement and conceptual understanding were measured using curriculum-aligned assessments validated through expert review. Data were analysed using descriptive statistics, paired-sample t-tests, and effect size estimates. The results showed statistically significant pretest–posttest gains in motivation, achievement, and conceptual understanding among students in the gamified instruction group, with moderate to large effect sizes, whereas students in the control group demonstrated minimal changes across the same measures. These findings indicate that curriculum-aligned gamified mathematics instruction is associated with enhanced student motivation, improved academic performance, and stronger conceptual understanding within the study context. The study contributes to mathematics education literature by providing large-sample quasi-experimental evidence on the concurrent affective and cognitive outcomes of gamified instruction in secondary mathematics classrooms in a developing educational setting.

Keywords: Gamification; Mathematics Education; Student Motivation; Mathematics Achievement; Conceptual Understanding.

INTRODUCTION

Mathematics education is still struggling with issues of student disengagement, lack of motivation and poor ability to comprehend abstract concepts. In most secondary school settings, students find mathematics to be challenging and unrelated to real life and this is what makes the subject less appealing and generates disparate achievement. Historical teaching practices are still prevailing in mathematics classes and may focus on procedural learning with minimal time to engage in long-term interactions, assessment, and learning about concepts. In past research, these teaching conditions have been linked to low motivation and poor academic results among the students (Debrenti, 2024).

The concept of Gamification which can be described as the implementation of elements of a game like points, leaderboards, and rewards to non game scenarios has been put forward as a way of teaching that has been aimed at helping students to remain engaged and persistent. Gamification has been analyzed in mathematics education as a tool of organizing learning experiences in a manner that facilitates engagement and effort persistence. Previous studies have found that gamified learning setting is associated with higher levels of student engagement and motivation and better learning outcomes compared with conventional teaching methods (Gruber and Fassbinder, 2025; Li et al., 2024).

It has been suggested through integration of gamified aspects into mathematics learning as a method of forming more interactive and goal oriented learning environments. These environments focus on progression, feedback, and task completion which are the factors that have been identified to be associated with student motivation and engagement (Zainuddin et al., 2020). Even though some studies have discussed motivational effects linked to gamification, fewer have also compared its connection to academic performance and conceptual knowledge in mathematics at the secondary school level.

Objectives of the Study

The following objectives guided the study

I. To explore the outcomes of gamification on student motivation in learning mathematics.

II. To determine whether gamification affects student achievement in mathematics.

III. To analyze the effect of gamified learning environments on conceptual learning of mathematics in students.

Research Questions

The following research questions lead the study.

I. What is the role of gamification in motivating students to learn mathematics.

II. How does gamified learning environments affect student performance in mathematics.

III. What is the effect of gamification on the conceptual learning of mathematical concepts in students.

Statement of the Problem

In spite of the prevalence of traditional methods of instruction in the mathematics learning classrooms, a significant number of students still exhibit lack of motivation, and inability to master abstract mathematical concepts. Whereas there are learners who can perform effectively in traditional teaching methods, there are learners, who have a hard time in remaining focused and acquiring in depth knowledge of concepts in mathematics. Gamification has been suggested as an alternative method of instruction where learning is organized in terms of feedback, progressiveness and interactive activities. Nonetheless, there has been limited empirical evidence on its relationship with student motivation, achievement, and conceptual knowledge in science education in mathematics at the secondary school level, especially in developing educational settings. This gap is filled by the present study which will discuss the relationship between gamified learning environments and various learning outcomes within the same instructional design.

Significance of the Study

This study contributes to mathematics education research by providing empirical evidence on the association between gamified instruction and student motivation, mathematics achievement, and conceptual understanding within a large secondary school sample. By examining affective and cognitive outcomes concurrently using a quasi-experimental design across multiple schools, the study extends existing research that has often relied on isolated outcomes or small-scale interventions. The findings offer practical insights for instructional planning and the integration of curriculum-aligned gamified strategies within secondary mathematics classrooms in similar educational contexts.

The research helps to fill the gaps in the mathematics education research because it analyzes the student motivation and mathematics performance and concept generalization simultaneously in the context of a single gamified instructional design, which is curriculum-based. In contrast to much of the literature to date, which tends to isolate motivational or achievement outcomes, or uses small-scale or short-term interventions, the current research paper uses a quasi-experimental design in several secondary schools to measure coordinated affective and cognitive outcomes. The research also builds on the previous literature on gamification by placing the study in a progressive learning environment where secondary-level empirical research is scarce. The study can serve as a design-sensitive source on the role of gamification in formal classroom instruction instead of as an independent tool of engagement by matching the gamified instructional functionality characteristics with the curriculum goals and assessment practices.

Literature Review

Gamification in mathematics education has been the subject of an increasing body of literature (note: over the last ten years), as the concept of engagement and learning outcomes has been receiving more and more attention (Debrenti, 2024, Zainuddin et al, 2020). A substantial portion of this has considered motivation in response to gamified learning, mostly finding a general increase in engagement and participation when game components are included in the classroom tasks, Gruber and Fassbender, 2025, Li et al, 2024. Nonetheless, the results regarding academic performance and abstract thinking are still disproportionate, and the results differ depending on the models of instructions, timeframes, and testing methods, Zeng et al, 2024.

The frequent weakness in this research is the usage of motivational results without cognitive learning indicators or the emphasis on achievement without considering student conceptual knowledge change, Galic and Yildiz, 2023, Hui and Mahmud, 2023. Moreover, most of the studies have limited samples or short term interventions, which limits extrapolation of the results in the context of normal secondary school environments, Ratinho and Martins, 2023. Studies of secondary school students in emerging educational settings have been scarce, yet the issue of student engagement and learning in mathematics continues to trouble, Zainuddin et al, 2020.

In order to overcome these shortcomings, the current review generalizes the research on gamification in mathematics education to three related outcome areas, which include student motivation, mathematics achievement, and conceptual understanding. It utilizes motivational, cognitive, and constructivist approaches to research the theorization of gamma instructional settings to shape the participation and learning of learners. This synthesis offers conceptual basis on the study design and how the current investigation builds up on the current work in the sense that it explores a combination of outcomes in a quasi experimental design.

Gamification in Mathematics Education.

Gamification in mathematics education The systematic application of game-related content in learning processes to define learner motivation and task motivation, Debrenti, 2024. Instead of operating as independent games, the gamified act of learning systems structure the instructional activities of a game-like environment, using elements like progression systems, feedback systems, and curricular-focused goal oriented challenges, Zainuddin et al, 2020. In mathematics classrooms, these aspects are to be used so that they can affect the way learners go about solving problem solving tasks and being able to maintain effort in the learning tasks.

The empirical research in the field of mathematics education indicates that gamified instructional designs are linked to a higher level of student engagement and time on task, especially when the feedback and progression indications are incorporated in the lesson design, Gruber and Fassbender, 2025. These engagement effects are usually associated with motivation processes since students are regularly informed about completing tasks and their performance state, which influences their readiness to proceed with working with mathematical problems, Li et al, 2024. Nonetheless, there are documented results that differ in accordance with the association of game components to instructional material and assessment activities, Zeng et al, 2024.

In addition to engagement, studies investigating the learning outcomes of games in mathematics settings show inconclusive results. Studies indicate that gamified tasks can enhance mathematics performance in a scenario whereby sustained practice and error correction are supported by game activities and that gamified tasks have no effect in a scenario where game activities are loosely tied to learning goals, Galic and Yildiz, 2023. Conceptual understanding Evidence thereof is less uniform, with a number of studies based on procedural tests that do not represent student capacity to explain and utilize mathematical concepts, Hui and Mahmud, 2023. Such trends imply that the designs should be developed to explore both affective and cognitive results in the same instructional situation.

The Role of Motivation in Mathematics Learning

The construct of motivation plays a pivotal role in mathematics education because it determines the willingness of students to undertake learning activities, to persevere in the face of a challenge and to exert effort in problem solving activities. Mathematics is generally regarded as a very difficult subject and thus motivation is exceptionally critical towards deep learning and performance. Previous studies have also consistently associated the increased levels of motivation with better engagement and academic outcomes in mathematics (Li et al., 2024).

The Self Determination Theory and Expectancy Value Theory have served theoretical frameworks on the impact of instructional environment on student motivation. Self Determination theory highlights the importance of autonomy, competence and relatedness towards intrinsic motivation. Gamified learning systems can facilitate such requirements by enabling the learner to perceive progress based on a structured task, timely feedback, and collaborative or competitive activities (Alkhawalde and Khasawneh, 2023). Research that implements this framework indicates that students who receive gamified instructions tend to have a higher level of intrinsic motivation than those who are in a classical classroom (Li et al., 2024).

The Expectancy Value Theory emphasizes the importance of beliefs of students regarding their capability to achieve and the perceived value of learning activities. Gamified environments can both promote expectations of success by using feedback and gradual challenges and promote the value of the task by making the learning activities more interesting (Zainuddin et al., 2020). Empirical research shows that these characteristics relate to greater student effort and mathematics learning persistence (Gruber and Fassbender, 2025).

Theoretical Foundations

Motivation Theories in Education.

Self Determination Theory and Expectancy Value Theory give the main theoretical basis to study the outcomes associated with motivation in gamified mathematics teaching, Deci and Ryan, 2000, Wigfield and Eccles, 2000. Self Determination Theory is a theory that describes motivation in the sense that it relates to fulfillment of autonomy, competence and relatedness in the learning contexts. Instructional structures that facilitate tracking of progress, feedback, and accomplishment of tasks in mathematics classroom influence the perception of competence and control of learning activities by students, Zainuddin et al, 2020. Gamified lesson plans tend to incorporate these characteristics in the daily classroom assignments, connecting the theory to the measured increase in intrinsic and extrinsic motivation.

The Expectancy Value Theory is a complementary approach to this position since it deals with the views of students towards success and the perceived value of the learning activity. Mathematics activities presented in terms of organized challenges and goals progressively lead to the belief in success as the performance requirements are clear and reachable, Li et al, 2024. Gamified learning environments as well affect task value, by changing student perceptions of effort and achievement, when undertaking mathematics learning tasks, Gruber and Fassbender, 2025. In this model, motivation is not considered as a general disposition but as a response to task structure and to feedback conditions incorporated in instruction.

Together, these theories explain how instructional design features in gamified mathematics environments shape motivational processes that precede learning outcomes. They provide a conceptual basis for examining changes in student motivation alongside achievement and conceptual understanding within the same instructional sequence. This alignment supports the use of motivation measures as outcome variables linked to instructional conditions rather than as isolated learner traits

Cognitive and Constructivist Theories.

Cognitive and constructivist perspectives provide the theoretical basis for examining conceptual understanding in gamified mathematics instruction. From a cognitive perspective, learning is shaped by how instructional tasks manage information processing demands and support meaningful engagement with content, Gruber and Faßbender, 2025. In mathematics classrooms, instructional designs that structure tasks into manageable steps and provide immediate feedback support learners ability to process and reorganize mathematical information during problem solving activities.

Constructivist theory emphasizes learning as an active process in which students build understanding through interaction with tasks and reflection on outcomes. In mathematics education, conceptual understanding develops when learners explain relationships, apply concepts across contexts, and revise reasoning based on feedback, Fosnot, 2013. Gamified learning environments often require students to engage repeatedly with concepts through structured challenges and explanation based tasks rather than through isolated procedural practice, Hui and Mahmud, 2023.

These perspectives clarify why conceptual understanding is treated as a distinct outcome from achievement in the present study. While achievement measures capture task performance and correctness, conceptual understanding assessments focus on explanation, application, and reasoning processes aligned with instructional tasks, Castillo et al, 2025. The integration of cognitive and constructivist principles supports the examination of how gamified instructional structures influence deeper understanding of mathematical concepts within the same learning sequence.

Gamification and Its Impact on Student Motivation

Motivational Effects of Gamification

Research examining the motivational effects of gamification consistently reports positive associations with student engagement and persistence. Gamified systems incorporate both intrinsic and extrinsic motivational elements, including enjoyment, challenge, rewards, and recognition. Studies indicate that students exposed to gamified mathematics instruction often report higher motivation levels than those taught through traditional approaches (Li et al., 2024).

Extrinsic rewards such as points and badges provide immediate indicators of progress, while intrinsic motivation may be supported through task enjoyment and achievement experiences. Research suggests that balanced integration of these elements is important to avoid overreliance on external rewards (Gruber and Faßbender, 2025; Zainuddin et al., 2020). When properly designed, gamified systems appear to support sustained motivation rather than short term engagement alone.

Engagement and Enjoyment in Mathematics

Engagement and enjoyment are closely related to motivation in mathematics learning. Gamification has been associated with increased enjoyment by transforming abstract concepts into interactive learning experiences (Ratinho and Martins, 2023). Studies report that students participating in gamified mathematics activities demonstrate higher levels of participation and time on task compared to traditional classroom settings (Ngandu et al., 2023).

Increased engagement has also been linked to improved retention and application of mathematical concepts. Research suggests that when students actively participate in structured learning activities, they are more likely to develop deeper understanding and problem solving skills (García López et al., 2023; Gruber and Faßbender, 2025).

Challenges and Limitations of Gamification in Mathematics Education

Design and Development Hurdles

Despite its potential benefits, gamification presents several design challenges. Poor alignment between game mechanics and learning objectives may reduce instructional effectiveness and distract from content learning. Research emphasizes the importance of carefully balancing rewards and learning goals to support intrinsic motivation rather than superficial engagement (Gruber and Faßbender, 2025; Zainuddin et al., 2020).

Technical and resource constraints also pose challenges, particularly in contexts with limited access to digital infrastructure. Developing and maintaining high quality gamified platforms requires expertise and institutional support, which may not be available in all educational settings (Alkhawalde and Khasawneh, 2023).

Implementation Issues in Diverse Settings

Learner differences and classroom contexts influence the effectiveness of gamification. Some students respond positively to competitive elements, while others may experience increased anxiety or disengagement. These differences are especially relevant in mixed ability classrooms (Li et al., 2024). In addition, unequal access to technology may limit the reach of gamified instruction in developing regions (Zainuddin et al., 2020).

Assessment of Learning Outcomes and Potential Negative Impacts

Assessing learning outcomes in gamified environments presents challenges, as traditional assessment methods may not capture ongoing engagement and conceptual development. Research suggests the need for assessment approaches that align with interactive and continuous learning processes (Castillo et al., 2025; Hui and Mahmud, 2023).

Potential negative effects of gamification include excessive competition and overemphasis on extrinsic rewards, which may undermine intrinsic motivation if not carefully managed. Prior studies highlight the importance of thoughtful design to mitigate these risks and support sustainable learning outcomes (Ryan and Deci, 2000; Gruber and Faßbender, 2025).

The reviewed literature indicates that gamification is associated with positive motivational and engagement outcomes in mathematics education, with mixed findings regarding achievement and conceptual understanding depending on context and design quality. While prior studies provide valuable insights, gaps remain in large scale empirical research that examines motivation, achievement, and conceptual understanding concurrently within the same instructional framework. Evidence from secondary school settings in developing educational contexts also remains limited. These gaps underscore the need for controlled studies that integrate multiple outcome measures and contextual considerations, which the present study seeks to address.

METHODOLOGY

Research Design

The research used a quasi experimental pretest posttest control group design to compare the difference in student motivation, mathematics achievement, and conceptual understanding in two conditions of instruction. Students could not be randomly allocated to groups because of the classroom and school set ups. Routine instructional practices in the public secondary schools were thus maintained using intact classes. This design enabled analysis on outcome differences between students that experienced a gamified mathematics learning condition and those that experienced conventional learning instruction on the same curricular content during the same learning period.

The quasi-experimental design was considered appropriate given the institutional constraints of the participating schools, where random assignment of students to instructional conditions was not feasible. The use of intact classes allowed the study to preserve natural classroom settings and instructional routines, thereby enhancing ecological validity. However, this design also limits causal inference, as pre-existing group differences cannot be fully ruled out. Consequently, the findings are interpreted as associative rather than causal.

Population and Sample

The population comprised students enrolled in public secondary schools in Northeast Nigeria. Fifteen schools were purposively selected based on similarities in curriculum implementation, grade level, and instructional timetables to ensure comparability across sites. Within each school, intact classes were assigned to either the experimental or control condition at the class level in order to minimise disruption to normal teaching practices. The final sample consisted of 700 students, with 350 students in the experimental group and 350 students in the control group.

Instructional Conditions

The experimental group of students were taught using a gamified learning environment of mathematics over four weeks. Instructional design has been used with progression based tasks, feedback mechanism and goal oriented activities in line with the curriculum objectives. In order to provide consistency in the schools, teachers using the gamified lessons adhered to a general teaching strategy. The control group was taught traditional mathematics that was delivered in the same content, at the same time, through teacher led explanations and routine exercises in the classroom. Both groups had the same instructional goals and evaluation timetables.

The gamified instructional condition incorporated structured goal-oriented tasks, progression indicators, and immediate feedback mechanisms aligned with lesson objectives, while avoiding standalone digital games or competition-based rewards unrelated to curricular content.

Instruments

Student motivation, mathematics performance and conceptual understanding were measured using three instruments. A modified version of the scale-based motivation scales of mathematics education was used to measure student motivation. The measure of intrinsic and extrinsic motivation that concerned learning mathematics was a tool that was used as a pretest and a posttest.

Achievement in mathematics was tested using a curriculum aligned test which was done to get the performance of students in respect to the instructional content. The test was aimed at accuracy of procedures and proper responses on problem solving. Conceptual knowledge was assessed through a different test that was created to measure the students knowledge in their capacity to explain mathematical concepts, as well as the ability to apply concepts to a related task. The separation between achievement and conceptual knowledge was kept in terms of variance in the structure and scoring points in items.

Achievement and conceptual understanding were treated as related but distinct constructs. Achievement items focused primarily on procedural accuracy and correct problem-solving outcomes, whereas conceptual understanding items required explanation, justification, or application of mathematical concepts to novel or related tasks. This distinction was reflected in item formats and scoring rubrics to ensure construct differentiation.

Validity and Reliability

Expert review was used to determine content validity of the achievement and conceptual understanding tests as it was deemed that the tests aligned with the curriculum objectives and instructional content. The motivation questionnaire was found to have acceptable internal consistency as Cronbach alpha coefficients of subscales varied between 0.78 to 0.86. Pilot testing on achievement and conceptual understanding tests was done before the main study and items were determined to be clear, and scoring procedures were found to be consistent.

Reliability estimates were calculated separately for pretest and posttest administrations, and all instruments met acceptable internal consistency thresholds for educational research.

Procedure

Student motivation, mathematics and conceptual understanding were measured using pretest measures that were administered to both groups prior to their intervention. The intervention was a teaching one that was practiced in four weeks. At the end of the intervention, the posttest measures were measured using the instruments and procedures of the two groups.

Data Analysis

Pretest and posttest scores of each group were summarized using descriptive statistics. To test changes in conditions of each instructional condition, paired sample t tests were performed. To estimate the magnitude of the changes that were observed the effect sizes were calculated using Cohen d. The level of statistical significance was determined to be 0.05.

The paired-sample t-tests were utilized to investigate within-group pretest-posttest differences since the major focus of their analysis was the outcome changes in each of the instructional conditions but not the direct comparisons of causality between groups. This method was deemed suitable in describing the observed changes with time, without the assumption of causal inference as would be necessary with random assignment since intact classes were used. The effect sizes (Cohen d) were provided to facilitate the interpretation of the magnitude of changes realized.

Ethical Considerations

Approval concerning the ethics was done by the appropriate institutional authority. School administrators gave permission before data collection. Students and their guardians were informed and gave their consent. Confidentiality of the participants was observed

RESULTS

The results are presented as within-group pretest–posttest changes for the experimental and control groups, consistent with the quasi-experimental design and analytic focus of the study.

Research Question 1: What is the role of gamification in motivating students to learn mathematics.

Table 1; Pretest and Posttest Motivation Scores for Experimental and Control Groups

Group	Motivation Dimension	Pretest Mean	Posttest Mean	Mean Difference	Cohen's d	p value
Experimental	Intrinsic motivation	3.45	4.10	0.65	0.82	0.002
Experimental	Extrinsic motivation	3.40	4.05	0.65	0.79	0.004
Experimental	Overall motivation	3.43	4.08	0.65	0.81	0.003
Control	Overall motivation	3.44	3.48	0.04	0.06	0.412

Note. Motivation was measured using a Likert-type scale. Experimental group (n = 350); control group (n = 350). Effect sizes are reported as Cohen's d.

Research Question 2: How does gamified learning environments affect student performance in mathematics.

Table 2 ; ***Pretest and Posttest Mathematics Achievement Scores for Experimental and Control Groups.***

Group	Achievement Area	Pretest Mean	Posttest Mean	Mean Difference	Cohen's d	p value
Experimental	Algebra	60.5	78.3	17.8	0.88	0.001
Experimental	Geometry	62.0	79.4	17.4	0.85	0.002
Experimental	Overall achievement	61.3	78.8	17.5	0.87	0.001
Control	Overall achievement	61.5	62.4	0.9	0.08	0.368

Note. Scores represent percentage performance on curriculum-aligned assessments covering algebra and geometry. Experimental group (n = 350); control group (n = 350).

Research Question 3 What is the effect of gamification on the conceptual learning of mathematical concepts in students.

Table 3; Pretest and Posttest Conceptual Understanding Scores for Experimental and Control Groups

Group	Conceptual Area	Pretest Mean	Posttest Mean	Mean Difference	Cohen's d	p value
Experimental	Algebraic concepts	62.3	80.2	17.9	0.90	0.001
Experimental	Geometric concepts	63.1	80.8	17.7	0.88	0.002
Experimental	Overall conceptual understanding	62.7	80.5	17.8	0.89	0.001

Group	Conceptual Area	Pretest Mean	Posttest Mean	Mean Difference	Cohen's d	p value
Control	Overall conceptual understanding	62.9	63.6	0.7	0.07	0.401

Note. Scores reflect performance on explanation- and application-based items assessed using a structured scoring rubric. Experimental group (n = 350); control group (n = 350).

DISCUSSION

This study contributes to the literature by providing large-sample, quasi-experimental evidence on how curriculum-aligned gamified mathematics instruction is associated with coordinated changes in student motivation, achievement, and conceptual understanding at the secondary school level.

This research paper investigated the variation in student motivation, mathematics performance and conceptual knowledge based on the involvement in a gamified mathematics learning environment in school based learning in the government secondary schools. The findings indicate that the students who engaged in the gamified instructional condition exhibited several pretest to posttest improvements on motivation, achievement, and conceptual understanding with little or no change being reported among students who were taught in the conventional way. These results answer the research questions as they indicate that the instructional structure was the dependent variable with respect to student interactions and learning of mathematics when curricular content and instruction time were kept constant.

One of the main results of the study is the concurrent improvement of affective and cognitive outcomes in the group of students who were exposed to a gamified instruction. Motivation was boosted in both intrinsic and extrinsic levels, mathematics performance improved in algebra and geometry Knowledge and conceptual learning were enhanced on tasks that involved an explanation and application of mathematical concepts. The coordinated pattern indicates that the gamified instructional design facilitated a variety of learning processes in the same sequence of instruction. This is not new in previous studies that have indicated this pattern when gamification incorporates feedback and goal oriented task progression into the mathematics lessons, especially when motivation and performance are studied collectively and not independently as was done by Li et al, 2024, Gruber and Fassbender, 2025.

The findings on motivation are in line with Self Determination Theory that describes motivation as a process of perceived competence and autonomy in the learning situations, Deci and Ryan, 2000. The gamified lessons used in the research involved structured collaborations and progressivities indications in tandem with what was done to tasks, which are instructional elements linked to better perceptions of competency in mathematics learning situations, Zainuddin et al, 2020. The Expectancy Value Theory also contributes to the explanations because learning was established in gamified activities and was supported by definite goals and challenges that could be achieved and might have contributed to the mindset of success and the worth of putting efforts in, Wigfield and Eccles, 2000. The same motivational benefits have been described in secondary math situations where gamification focuses on feedback transparency and an achievement meter as opposed to competition, Ratinho and Martins, 2023.

Findings of the achievement reveal that students in the gamified instruction group showed significant gains in math performance, and small gains in achievement of the students in the control group are realized. These findings are consistent with the existing research which claimed that gamified instructional designs help to maintain engagement with practice activities and reinforce learning with the help of prompt feedback, Zeng et al, 2024. Since the instructional groups had the same curriculum and schedule to be assessed, the observed variances are more likely to be related with the design of instructions rather than content exposure. This observation promotes some evidence indicating that the arrangement and sequence of mathematics tasks relate to student performance outcomes in accordance with the curriculum goals, Debrenti, 2024.

The results regarding conceptual understanding expands the research that has been conducted on gamification in mathematics education. The gamified learning environment showed better performance in terms of how the students are able to explain and implement mathematical concepts and the understanding of the concepts among the students who got conventional instruction was not significantly different. Constructivist views underline the fact that conceptual knowledge can be formed by means of activity and reflection as opposed to the procedure of repetition itself, Fosnot, 2013. The gamified activities involved the repetitive exposure to mathematical concepts using structured challenges and explanation by activities, both of which are in line with the instructional conditions related to the deeper understanding, Hui and Mahmud, 2023. In previous studies, conceptual knowledge has been found to be poorly studied in gamification research since the method has been based on procedural measurement, Castillo et al, 2025. The current experiment fills this gap by differentiating performance and theoretical knowledge using different evaluation tools.

Collectively, the results suggest that motivation, achievement, and conceptual understanding occurred in a coordinated way with students subjected to gamified instruction. This coordination can be utilized to affirm perspectives which perceive motivation as a component of instructional activity, and not an autonomous learner characteristic, Li et al, 2024. Meanwhile, causal interpretation cannot be done due to the quasi experimental design and the use of intact classes. The differences that we have observed should be taken as relationships in the study, not as the effects that can be applied to gamification only.

The findings have a number of limitations that should be taken into consideration when interpreting them. The application of intact classes brings the risk of having pre existing group differences that was not properly controlled. Its analysis was on within group change as opposed to direct between group comparison, which limits the causal inference. The four weeks intervention time constrains description of (long term) patterns of learning. The research was done in a particular regional context in a secondary school setting, and this might not be generalized to other regions that might have varying instructional resources or institutional contexts.

Despite such limitations, the study adds to the body of research in mathematics education through studying motivation, achievement, and conceptual understanding simultaneously in the same instruction design and a large grade 12 population sample. Previously, such outcomes have been investigated individually or based on small scale interventions, Gruber and Fassbender, 2025, Zainuddin et al, 2020. The results indicate that matching the aspects of gamification to curriculum goals and assessment activities are more significant than considering gamification an independent teaching supplement. To use in the classroom, the findings suggest that systematised gamified methods can facilitate student interaction and learning as part of the established curricular systems.

Future studies ought to look at longer interventions and carry out designs that would permit greater control of group variations. Research performed in a variety of educational settings would explain how gamified educational characteristics would be performed in different situations. Studies, which isolate individual aspects of gamification including feedback scheme or progression mechanisms, would help more in understanding the mechanisms by which instructional design relates to motivation, achievement and conceptual insight.

CONCLUSION

This research paper gives strong support to the beneficial role of gamification on student motivation, performance and abstract learning in mathematics. The results indicate that gamified learning conditions are useful in enhancing student engagement, better performance in academic fields, and understanding of mathematical concepts by students. Gamification presents a good way to solve the problem of student disengagement and inability to grasp abstract concepts in mathematics.

The paper identifies the literature gap that requires further investigation of the concept of gamification in education, especially in mathematics. Due to the favorable results of this research, it is advisable to recommend teachers to include gamified systems in their pedagogy and ensure a more interactive and active approach to learning. More studies on the long-term impact of gamification on student learning and creation of inclusive gamified tools enabling different educational settings should be conducted.

I. Teachers need to incorporate gamified instructional features of structured feedback and goal oriented work into mathematics classes without violating curriculum goals and assessment activities.

II. The administrators and curriculum planners of the school should encourage the professional development that aims at the instruction design approaches that integrate the engagement strategies with the possibility of conceptual learning and long-term practice.

III. Future studies should be planned by researchers with longer intervention duration and enhanced experimental manipulation to determine the relationship between certain gamification characteristics and motivation, achievement and conceptual mastery in different educational settings.

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