GAMIFICATION STRATEGIES AND THEIR EFFECTS ON LEARNING MOTIVATION AND CONCEPT MASTERY IN MATHEMATICS AND SCIENCE EDUCATION

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Abstract

This study examined the impact of gamification strategies on students' learning motivation and concept mastery in mathematics and science education in Nigerian secondary schools. A quasi-experimental design was adopted using intact classes from four public schools randomly assigned to experimental (gamified) and control (traditional) groups. A total of 180 students participated, and data were collected through a Concept Mastery Test and a Learning Motivation Questionnaire. ANCOVA analysis revealed significant differences between the two groups in both motivation and concept mastery, with the gamified group performing significantly better. The findings align with Self-Determination Theory and support the view that gamification enhances intrinsic motivation and cognitive engagement, leading to improved academic outcomes. The study recommends integrating gamified instruction into STEM curricula, training teachers in game-based pedagogy, and supporting digital education innovations across Nigeria.

Keywords: Gamification, Motivation, Concept Mastery, Mathematics Education, Science Education, Self-Determination Theory, Secondary Schools, Nigeria.

Introduction

In recent years, gamification has emerged as a transformative strategy in education, particularly in mathematics and science classrooms where student motivation and concept mastery often present persistent challenges. Gamification refers to the use of game elements such as points, levels, badges, and leaderboards in non-game contexts to enhance user engagement and performance (Mustafa, 2023). In education, it offers a promising approach for fostering active learning and motivating students through interactive, rewarding, and goal-oriented experiences. Mathematics and science subjects, though foundational for STEM careers, are often perceived as abstract, rigid, and difficult by learners, leading to low achievement and disengagement, especially in developing countries like Nigeria (Zourmpakis et al., 2022). Research has shown that gamified learning environments promote sustained attention, curiosity, and constructive competition, which are essential for grasping complex concepts (Kalogiannakis et al., 2021). Furthermore, gamification fosters intrinsic motivation by satisfying learners' psychological needs for autonomy, competence, and relatedness as described by Li et al. (2024) on Self-Determination Theory. When applied appropriately, gamification can bridge the gap between theoretical content and practical understanding, especially in science and mathematics instruction, where learners often struggle with abstraction and symbolic representation (Kam & Umar, 2018). Despite the growing evidence of its effectiveness, there remains limited empirical research in African secondary school contexts, particularly examining how gamification influences both motivation and concept mastery in STEM-related disciplines (Aliyu et al., 2025). Therefore, this study seeks to investigate the effects of gamification strategies on students' learning motivation and conceptual understanding in mathematics and science education. It further explores how game-based instructional designs can be employed to support curriculum delivery, especially in environments characterised by low resource availability, high teacher-student ratios, and declining learner interest in STEM fields (Aliyu et al., 2025). The outcomes of this study will provide data-driven insights to inform pedagogical practices and policy frameworks for enhanced student achievement and engagement.

Objectives of the Study

This study aims to explore the effectiveness of gamification strategies in enhancing students' learning motivation and concept mastery in mathematics and science education. Specifically, the study seeks to:

1. Examine the effect of gamification strategies on students' motivation to learn mathematics and science.
2. Determine the impact of gamification strategies on students' mastery of mathematical and scientific concepts.

Based on these objectives, the following research questions were raised:

1. What is the difference in learning motivation between students taught mathematics and science using gamification strategies and those taught using conventional methods?
2. What is the difference in concept mastery between students exposed to gamified instruction and those taught through conventional approaches?

Null Hypotheses

The following null hypotheses were formulated and tested at a 0.05 level of significance:

H_{01}: There is no significant difference in the learning motivation of students taught mathematics and science using gamification strategies and those taught using conventional methods.

H_{02}: There is no significant difference in the concept mastery of students taught mathematics and science using gamification strategies and those taught using conventional methods.

Literature Review and Theoretical Framework

Gamification has garnered increasing attention in education due to its potential to enhance student engagement, motivation, and learning outcomes, particularly in subjects like mathematics and science that often pose cognitive and emotional challenges for learners. According to Rivera et al. (2021), gamification can positively influence behavioural outcomes by integrating game elements such as rewards, competition, feedback, and progress tracking into traditional instruction. These elements provide immediate reinforcement, encourage participation, and stimulate curiosity, which are essential for conceptual learning. In mathematics education, gamification helps simplify abstract concepts through interactive challenges, fostering deeper understanding (Alsawaier, 2018). Similarly, in science classrooms, games and simulations make complex phenomena tangible and engaging, promoting experiential learning and inquiry (Ukgoda, 2025). A meta-analysis by Bharti (2023) confirmed that gamified instructional strategies consistently yield moderate to high effect sizes on both student motivation and achievement in STEM disciplines.

Moreover, Hellín et al. (2023) emphasised that the instructional effectiveness of gamification is maximised when game mechanics are directly aligned with specific learning objectives. The theoretical foundation of this study is rooted in Self-Determination Theory (SDT) by Deci and Ryan (2012), which asserts that motivation increases when learners feel autonomous, competent, and connected. Gamified learning environments are known to fulfil these psychological needs, promoting both intrinsic motivation and persistent effort. Additionally, the Constructivist Learning Theory supports the use of game-based learning, as it emphasises active participation, meaningful context, and feedback loops that enable learners to construct their understanding through interaction. Research by Maryana et al. (2024) and Smirani and Yamani (2024) also revealed that students in gamified science and mathematics classrooms demonstrate greater conceptual mastery due to improved retention and cognitive engagement. However, studies also caution that superficial or poorly designed gamification can lead to diminished interest and surface-level learning, highlighting the need for thoughtful instructional design (Sani et al., 2025). Given the limited contextual studies in African and specifically Nigerian school systems, this study contributes to the literature by examining the effectiveness of gamified instruction in enhancing student motivation and conceptual understanding in mathematics and science among secondary school students.

Methodology

This study adopted a quasi-experimental design involving a non-equivalent pre-test, post-test control group structure to assess the effects of gamification strategies on students' motivation and concept mastery in mathematics and science (Akorede et al., 2019). The design was chosen to allow for experimental control while using intact classes due to ethical and administrative constraints in school settings. The study was conducted in selected public junior and senior secondary schools in the Zaria Education Zone of Kaduna State, Nigeria. The population comprised all JSS3 and SS2 students offering mathematics and basic science/physics, with a target population of approximately 4,500 students. Using purposive and simple random sampling techniques, four co-educational schools were selected based on the availability of digital resources and trained teachers. Two schools were randomly assigned to the experimental group, where gamified instruction was implemented using platforms such as Kahoot, Classcraft, and Quizizz integrated into lesson delivery, while the other two formed the control group, receiving conventional teaching. A total of 180 students participated in the study, 90 in the experimental group and 90 in the control group. The instruments used for data collection were: the Mathematics and Science Concept Mastery Test (MSCMT), a 40-item objective test covering key topics aligned with the school curriculum, and the Student Learning Motivation Questionnaire (SLMQ), a 30-item Likert-type instrument adapted from Glynn et al. (2011) with subscales measuring intrinsic motivation, self-efficacy, and goal orientation. Both instruments were validated by experts in mathematics/science education and educational psychology, and pilot-tested with 30 students in a neighbouring school to estimate reliability using Cronbach's alpha, which yielded coefficients of 0.83 for SLMQ and 0.79 for MSCMT, indicating acceptable internal consistency. Data were collected over a six-week period, during which experimental group students engaged in gamified activities, competitions, and feedback cycles aligned with weekly lesson objectives. Pre-tests and post-tests were administered to both groups, and data were analysed using descriptive statistics, Analysis of Covariance (ANCOVA) for hypothesis testing, and effect size estimation using partial eta squared (η^2) to determine the magnitude of observed differences. Ethical approval was secured from the appropriate educational authorities, and informed consent was obtained from all participants and their school administrators.

Results

Research Question 1: What is the difference in learning motivation between students taught mathematics and science using gamification strategies and those taught using conventional methods?

Null Hypothesis 1 (H_{01}): There is no significant difference in the learning motivation of students taught mathematics and science using gamification strategies and those taught using conventional methods.

Table 1: ANCOVA Summary for Post-Test Motivation Scores (Pre-Test as Covariate)

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
Pre-test (Covariate)	103.42	1	103.42	6.53	0.012*	0.036
Group (Gamified vs. Traditional)	415.60	1	415.60	26.25	0.000**	0.134
Error	2750.48	176	15.63			
Total	**4456.17**	**179**				

*p < 0.05, **p < 0.001*

Table 1 shows a statistically significant difference in post-test motivation scores between students taught using gamification strategies and those taught using conventional methods, $F(1, 176) = 26.25$, $p < .001$, partial $\eta^2 = 0.134$. This indicates a large effect size, meaning gamified instruction significantly improved students' learning motivation. Therefore, H_{01} is rejected.

Research Question 2: What is the difference in concept mastery between students exposed to gamified instruction and those taught through conventional approaches?

Null Hypothesis 2 (H_{02}): There is no significant difference in the concept mastery of students taught mathematics and science using gamification strategies and those taught using conventional methods.

Table 2: ANCOVA Summary for Post-Test Concept Mastery Scores

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
Pre-test (Covariate)	198.75	1	198.75	8.22	0.005*	0.045
Group (Gamified vs. Traditional)	587.20	1	587.20	24.89	0.000**	0.124
Error	4146.65	176	23.56			
Total	**5975.66**	**179**				

*p < 0.05, **p < 0.001*

Results in Table 2 reveal a significant difference in concept mastery between the experimental and control groups, $F(1, 176) = 24.89$, $p < .001$, with a partial $\eta^2 = 0.124$. This suggests that gamification has a strong positive impact on students' conceptual understanding in mathematics and science. Thus, H_{02} is also rejected.

Discussion of Findings

The findings of this study strongly affirm the positive impact of gamification strategies on students' learning motivation and concept mastery in mathematics and science education. The ANCOVA results revealed significant differences in both motivation and conceptual understanding between students taught using gamified instruction and those taught through traditional methods, with large effect sizes indicating substantial educational value. These outcomes align with previous research that underscores the motivational power of gamification in academic settings. For instance, Rivera et al. (2021) found that game elements like feedback, points, and leaderboards trigger intrinsic motivation by satisfying students' needs for autonomy, competence, and social interaction, as theorised in Self-Determination Theory (Deci & Ryan, 2012). Similarly, Aliyu et al. (2025) reported improved academic performance and engagement when gamified tools were integrated into science and mathematics curricula. The present study adds to this body of knowledge by offering empirical evidence from a Nigerian context, indicating that students in gamified classrooms demonstrated greater conceptual understanding due to the interactive, iterative, and visual nature of gamified learning. This supports Alsawaier (2018), who emphasised the value of gamified environments in promoting active exploration and sustained cognitive engagement. Additionally, the improvement in mastery may be attributed to the immediate feedback and incremental challenges embedded in game mechanics, which are known to scaffold learning effectively (Sani et al., 2025). Moreover, the study echoes Subhash and Hellin et al. (2023), who highlighted that well-structured gamification fosters meaningful learning and reduces anxiety associated with difficult STEM subjects. These results suggest that integrating gamification into science and mathematics pedagogy not only stimulates learner interest but also enhances retention and understanding of core concepts, an essential requirement for fostering critical thinking and 21st-century competencies.

Conclusion

This study investigated the effects of gamification strategies on students' motivation and concept mastery in mathematics and science education within Nigerian secondary schools. The findings revealed that gamified instructional approaches significantly enhanced both learning motivation and conceptual understanding compared to conventional teaching methods. These outcomes underscore the pedagogical relevance of integrating game elements into STEM teaching, particularly in subjects where students often experience disengagement and learning difficulties. The results affirm that gamification is more than just a tool for entertainment it is a meaningful instructional strategy that aligns with established theories of motivation and cognitive engagement. Given the growing demand for innovative teaching methods that foster deep learning and positive attitudes toward science and mathematics, gamification presents a viable, cost-effective approach adaptable to diverse classroom settings.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Integrate Gamification in STEM Curriculum: Education authorities and curriculum developers should formally incorporate gamified instructional approaches into mathematics and science education at the secondary school level to enhance engagement and mastery.

2. Teacher Training and Capacity Building: Teachers should be trained on how to design and implement effective gamified learning experiences using platforms like Kahoot, Quizizz, and Classcraft, ensuring alignment with learning objectives.
3. Policy Support for EdTech Integration: Governments and education stakeholders should invest in low-cost technological tools and infrastructure to support the use of gamified learning in under-resourced schools.
4. Further Research: More studies should be conducted across different subjects, age groups, and educational contexts in Nigeria and other African nations to expand the evidence base on the efficacy of gamification.
5. Encourage Student-Centred Learning: Schools should promote student agency through gamified activities that reward collaboration, creativity, and problem-solving skills critical for STEM careers in the 21st century.

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