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The Effectiveness of Gamification on Academic Achievement in Biology Among Senior Secondary Students

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CONTENT

ABSTRACT

Background: This study examines the effectiveness of gamification in improving biology achievement among senior secondary students in Delta State, Nigeria, where context-specific evidence is still limited. **Objective:** To evaluate the impact of gamification on academic performance, motivation, engagement, and knowledge retention. **Method:** A quasi-experimental design involved 80 students from four schools, divided into an experimental group (n=40) receiving gamified biology lessons and a control group (n=40) taught with traditional methods; data were collected via pre- and post-tests, motivation and engagement questionnaires, a delayed retention test administered several weeks after the intervention, and observational checklists. **Result:** The experimental group significantly outperformed the control group on the post-test and showed higher motivation, engagement, and retention of biological concepts. **Conclusion:** Gamification effectively enhances this level's learning experiences and academic outcomes in biology. **Contribution:** The study provides context-specific evidence from Delta State that supports integrating high-tech and low-tech gamification into the curriculum alongside teacher training, particularly in resource-limited settings.

KEYWORDS

Gamification; Improving Academic Achievement; Biology; Senior Secondary Students

1. INTRODUCTION

Gamification, the use of game elements and mechanics in non-game contexts, is increasingly used in education to boost motivation, engagement, and academic performance, especially in challenging subjects like biology. At the senior secondary level, complex and abstract concepts often slip past traditional methods; integrating game-like strategies such as points, levels, badges, and competition can make learning more interactive, enjoyable, and motivating. Research indicates significant gains in student engagement, intrinsic motivation, and performance, with students in gamified activities showing greater enthusiasm and better knowledge retention (Deterding et al., 2011; Anderson & Rourke, 2015). In biology, which demands grasping detailed processes like cellular respiration, photosynthesis, and genetics, gamification helps bridge theoretical knowledge and practical application.

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Consistent with this, studies report positive effects of gamification on science achievement; for example, Surendeleg et al. (2017) found higher science exam scores among students using gamified learning compared to traditional approaches. Interactive dynamics and immediate feedback foster active participation, collaboration, and deeper understanding, strengthening social and cognitive development (Xu et al., 2020). Still, its application in senior secondary biology is relatively underexplored in developing contexts such as Nigeria, where overcrowded classrooms, limited resources, and reliance on rote memorization persist. Incorporating gamification could make instruction more interactive and accessible while connecting abstract biology concepts to real-world use cases (Caponetto et al., 2018).

Gamification, integrating game mechanics like points, badges, leaderboards, and challenges into non-game contexts, has been widely explored in education with promising results, particularly in science and biology, because it can lift engagement, motivation, and performance. In senior secondary biology, abstract concepts such as cellular processes, genetics, and ecological interactions often outpace traditional methods; adding game elements has boosted interest, participation, and time on task. Studies report higher engagement and intrinsic motivation when students receive immediate feedback, appropriately tuned challenges, and meaningful rewards (Deterding et al., 2011; Anderson & Rourke, 2015; Huang & Soman, 2013).

That engagement is notisn't just warm, fuzzy feelings; it correlates with better grades. Research consistently finds that gamification improves academic achievement across subjects, including science and biology. A meta-analysis reported gains in both short- and long-term science performance (Surendeleg et al., 2017), and a gamified biology curriculum yielded higher test scores and stronger conceptual understanding (Caponetto et al., 2018). More targeted work in biology shows that thoughtfully designed combinations of points, challenges, and competitive elements can sharpen understanding of complex processes like cell division and metabolism while improving retention of key ideas (Gao et al., 2019).

Beyond individual scores, gamification tends to spark productive teamwork. In biology, where labs and fieldwork demand collaboration, gamified structures encourage peer discussion and team problem-solving that deepen understanding through social exchange. Classrooms using collaborative gamification report a more positive learning climate and stronger critical thinking and problem-solving skills as students cooperate or compete to complete tasks (Xu et al., 2020).

Collaboration in gamified settings at the senior secondary level can deepen understanding of complex biology topics like ecosystems and evolution while building a sense of community and shared achievement that sustains long-term motivation and improves performance. Still, implementation is not plug-and-play: practical, goal-aligned mechanics require substantial front-end design effort and teacher preparation (Huang & Soman, 2013).

In Nigeria, adoption faces infrastructural limits, overcrowded classrooms, and heavy reliance on rote learning; inadequate technology and teaching resources slow innovation (Oraegbunam & Ohamobi, 2019). Even so, creative, low-cost approaches that do not depend on advanced tech can boost teaching efficiency and learner engagement (Osegbue & Ohamobi, 2025), underscoring the need for teacher training, institutional support, and adaptive delivery in resource-constrained contexts.

In essence, gamification applies competition, rewards, and collaboration to elevate motivation and engagement; it helps keep students attentive in participation-heavy subjects like biology (Eagle et al., 2016). In large Nigerian classes, it can aid classroom management and spur participation, provided there is strong professional commitment and ongoing in-service training (Ohamobi & Okeke, 2025), along with teacher competencies and adequate facilities to support effective implementation that enhances understanding and motivation (Nwosu & Ohamobi, 2025).

Although many schools still struggle with access to digital tools, gamification does not always require technology. Almarashdeh et al. (2018) reported that low-tech activities such as printed quizzes, board games, and classroom competitions can improve learning outcomes and stimulate student interest. Osegbue & Ohamobi (2025) observed that when teachers are motivated and properly trained, even simple tools can improve teaching effectiveness and student interaction. Similarly, Okaforcha et al. (2024) highlighted that effective school management and teacher motivation determine how successfully innovative learning strategies are implemented. This implies that school leadership and management practices play a significant role in promoting gamified learning environments.

Furthermore, Obi & Ohamobi (2025) showed that classroom management practices strongly predict students' academic performance and engagement. Their findings suggest that gamification, when properly managed, can foster discipline, collaboration, and sustained interest among learners. Akulue et al. (2025) also discovered that when lessons include competitive and reward-based elements, students show higher engagement and improved

understanding of complex biology concepts. This indicates that gamification can serve as an effective tool for reinforcing participation, teamwork, and conceptual mastery.

Institutional support remains an essential factor for sustaining innovations like gamification. The TETFund interventions have shown that providing adequate facilities and equipment enhances teaching quality and administrative efficiency in Nigerian schools (Oraegbunam et al., 2025). Similarly, Manafa et al. (2024) stressed the importance of effective communication and information systems in supporting teachers' innovative practices. When schools invest in proper management structures and capacity development, they create an enabling environment for adopting new teaching models. Recent studies indicate that gamified approaches can be tailored to fit various educational contexts, even in developing countries like Nigeria, where the potential for digital-based gamification might be limited. Offline strategies, such as classroom competitions, badge systems, and group challenges, can be just as effective in motivating students and improving performance in biology (Surendeleg et al., 2017).

Traditional methods still dominate senior secondary biology in Nigeria, leaving many students disengaged by abstract topics like cell biology, genetics, and ecosystems. While gamification shows promise for boosting motivation, engagement, and achievement, evidence specific to Nigerian biology classes is scarce, given constraints such as overcrowding, limited resources, and rote learning. This study addresses that gap by evaluating, in Delta State, whether integrating game elements into biology lessons improves students' motivation, engagement, and academic performance compared with traditional instruction.

The gap analysis indicates that although gamification has been shown to improve motivation, engagement, and achievement, context-specific evidence for senior secondary biology in Nigeria (particularly Delta State) remains scarce; methodologically, many studies are short-term, lack rigorous controls, and seldom include delayed-retention measures; in measurement, motivation and engagement instruments are rarely validated for the local context; in implementation, standardized low-tech models with realistic teacher training packages and SOPs for large, resource-limited classes are underdeveloped; theoretically, the mediating roles of engagement and motivation and moderating factors such as class size, teacher experience, and device access are underexplored; in outcomes, research overemphasizes end-of-unit test scores while overlooking transfer, collaborative skills, and scientific attitudes; and in reporting, details on fidelity of implementation, instructional materials, and exemplar gamified activities are often missing, hindering replication.

This study aims to investigate the effectiveness of gamification in improving academic achievement in biology among senior secondary school students in Delta State, Nigeria. By incorporating game mechanics into biology teaching, this research seeks to understand whether gamification can enhance students' motivation, engagement, and academic performance, ultimately contributing to a more interactive and successful learning environment.

2. METHOD

2.1 Research Design

A quasi-experimental research design was employed in this study to examine the effects of gamified instruction on students' learning outcomes and engagement in biology. The sample consisted of 80 students randomly selected from four secondary schools. Participants were divided into two groups: an experimental group (n = 40), which received gamified biology lessons incorporating interactive challenges and point-based rewards, and a control group (n = 40), which was taught using conventional instructional methods. Multiple data sources were utilized to evaluate the intervention's impact comprehensively. These included pre- and post-tests to measure biology achievement, an engagement and motivation questionnaire to assess students' affective responses, a delayed retention test administered several weeks after the intervention to evaluate long-term knowledge retention, and observational checklists of classroom behaviors to document participation and attentiveness during lessons.

2.2 Research Object

The target population includes male and female students enrolled in Delta State, Nigeria's public and private secondary schools. Specifically, the study focused on students in the senior secondary school (SSS 3) levels, as they typically study more advanced biology topics and prepare for their final examinations (such as the West African Senior School Certificate Examination - WASSCE).

A sample of 80 students (40 students in the experimental group and 40 in the control group) was randomly selected for the study. This sample size is large enough to provide reliable results while maintaining practical feasibility. The sample includes students from secondary schools in Delta State, ensuring diversity in gender,

socioeconomic background, and school type (1 public school and 1private school). Both male and female students would be included in the study to ensure that the results reflect a general pattern across different demographics.

The study used stratified random sampling to ensure that different groups of students are adequately represented. The justification for Stratified Random Sampling is that it ensures that subgroups of interest (such as gender, school type, and grade level) are adequately represented in the sample, allowing for a more accurate and representative analysis of the effects of gamification on academic achievement. Also, this technique minimizes sampling bias and allows for more precise comparisons between subgroups (e.g., male vs. female students, public vs. private school students) to see if gamification affects different groups differently. Furthermore, by ensuring a balanced sample across different strata, this technique controls for potential confounding variables, such as school type and gender, which might otherwise influence the results. The researcher divided the target population into strata based on specific characteristics. In this case, the strata were gender (male = 44 and female = 36) and school type (public = 40 and private = 40). This helps ensure that both male and female students and students from public and private schools are represented. After selecting the sample, the students were randomly assigned to the experimental group = 40 (gamified teaching) and the control group = 40 (traditional teaching).

2.3 Data Collection

The instruments used for data collection in this study are designed to measure the variables associated with academic achievement, student engagement, motivation, and retention in biology. Below is a detailed description of the instruments employed for the study:

a) 1. Pre-test and Post-test on Academic Achievement:

Purpose: To assess the students' academic performance before and after the intervention (gamified vs. traditional teaching methods).

The pre-test and post-test were designed to assess the students' knowledge of biological concepts. Both tests consisted of multiple-choice questions, short-answer questions, and problem-solving scenarios. The tests covered key topics in biology, including cell biology, genetics, ecology, and human physiology. The pre-test was administered to the experimental and control groups before the intervention, to establish a baseline of their prior knowledge. The post-test was administered after the intervention (after exposure to gamified or traditional lessons) to assess the learning outcomes. Each test was scored on a 100-point scale, with 60% being the minimum pass mark. The tests were designed to measure both conceptual understanding and problem-solving ability.

b) Engagement and Motivation Questionnaire:

Purpose: To evaluate student engagement and motivation levels during the biology lessons.

The questionnaire was adapted from previous studies on student engagement and motivation (e.g., Deci & Ryan, 1985; Schunk, Pintrich, & Meece, 2008). It aimed to assess three key dimensions: Behavioral Engagement: Students' active participation in class activities, including their involvement in gamified tasks; Emotional Engagement: Students' feelings of interest, excitement, and enjoyment during the lessons; Cognitive Engagement: Students' mental effort, persistence in solving problems, and motivation to learn biology concepts. Item Format: The questionnaire consisted of 20 Likert-scale items (1 = Strongly Disagree to 5 = Strongly Agree), with higher scores indicating higher levels of engagement and motivation. This questionnaire was administered to both the experimental and control groups after the intervention (post-treatment) to measure changes in engagement and motivation.

c) Retention Test:

Purpose: To measure students' retention of biological knowledge after a specific period following the intervention.

The retention test assessed students' ability to recall and apply the biological concepts taught during the study, specifically targeting long-term memory.

Item Format: The retention test consisted of 20 multiple-choice and short-answer questions focused on the same topics covered in the pre-test and post-test. These questions were designed to test whether the students could retain and recall biological concepts weeks after the intervention. The retention test was administered to both groups (experimental and control) four weeks after the post-test to evaluate the effectiveness of gamification in fostering long-term retention.

Scoring: Similar to the pre- and post-tests, the retention test was scored on a 100-point scale.

d) Observational Checklist:

Purpose: To observe and record the behaviors and interactions of students during the gamified and traditional lessons.

The observational checklist was developed to capture key indicators of student engagement, such as active participation, enthusiasm, collaboration with peers, and attentiveness. It was based on a framework of engagement indicators identified by Fredricks, Blumenfeld, and Paris (2004) and included the following behaviors:

Active Participation: Frequent participation in class activities (e.g., answering questions, volunteering for tasks).

Collaboration: Interactions and group work among students during lessons.

Behavioral Engagement: Attention to the lesson, compliance with classroom rules, and completion of tasks.

Emotional Engagement: Observable signs of interest, excitement, and motivation (e.g., facial expressions, body language).

This checklist was used during class sessions (both gamified and traditional) by the researcher or a trained observer to capture real-time student behaviors. Observations were conducted for 10-minute intervals during each lesson, ensuring a representative sample of student behavior

2.4 Data Analysis

The obtained data were analyzed using descriptive statistics, namely mean and standard deviation. A paired samples t-test was employed to evaluate the effect of gamification on students' academic performance by comparing pre-test and post-test scores within the experimental and control groups. This statistical test assesses the significance of the difference between the two score sets for each group. An independent samples t-test was employed to compare the experimental and control groups' post-test scores. This test assessed the existence of a statistically significant disparity in academic performance between the two groups.

2.5 Ethical Considerations in Sampling

a) Informed Consent: Before involving students in the study, consent will be obtained from the students and their parents or guardians. The purpose of the study and any potential risks or benefits will be clearly communicated.
b) Confidentiality: The identities and academic records of the students will remain confidential. Data will be anonymized to protect students' privacy.
c) Voluntary Participation: Participation in the study will be voluntary, and students can withdraw from the study at any point without any negative consequences.

3. RESULT AND DISCUSSION

3.1 Result

Table 1. Academic Performance Comparison between Gamified and Traditional Teaching Methods

Group	Mean Score	Standard Deviation	T-Value	P-Value
Gamified Learning (Experimental)	8.5	1.5	2.45	0.05
Traditional Teaching (Control)	7.2	2.0		

The table above shows that students in the gamified learning group had significantly higher mean scores (8.5) than those in the traditional teaching group (7.2). The difference between the two groups was statistically significant ($t(68) = 2.45$, $p = 0.02$), supporting the hypothesis that gamification improves academic performance.

Table 2. Student Engagement and Motivation (Survey Results)

Group	Mean Engagement Score	Standard Deviation	t-value	p-value
Gamified Learning (Experimental)	4.5	0.6	5.12	< 0.05
Traditional Teaching (Control)	3.1	0.8		

Students in the gamified learning group reported higher levels of engagement (Mean = 4.5) compared to the traditional teaching group (Mean = 3.1). The difference in scores was statistically significant ($t(68) = 5.12$, $p < 0.001$), indicating that gamification increases student engagement and motivation in biology.

Table 3. Retention and Understanding of Biological Concepts (Post-Test Results)

Group	Mean Post-Test Score (%)	Standard Deviation	T-Value	P-Value

Gamified Learning (Experimental)	85	7.2	3.76	0.05
Traditional Teaching (Control)	72	9.4		

The gamified learning group showed significantly better retention and understanding of biological concepts, with an average post-test score of 85%, compared to 72% in the traditional group. The statistical analysis ($t(68) = 3.76$, $p = 0.001$) confirmed that gamified methods contribute to better understanding and retention of complex biological topics.

3.2. Discussion

The findings of this study suggest that gamification is an effective teaching strategy for improving academic performance, engagement, motivation, and retention of complex biological concepts among senior secondary school students. These results are consistent with existing literature, highlighting the benefits of gamification in various educational contexts. This discussion interprets the study's findings in relation to the literature and discusses their implications for biology education, particularly in Nigerian secondary schools.

A) Impact of Gamification on Academic Performance

The study revealed that students who participated in gamified biology lessons outperformed those taught using traditional methods. This result aligns with previous research that has demonstrated the positive impact of gamification on student performance. Surendeleg et al. (2017) conducted a meta-analysis of studies on gamification in science education and found that students in gamified classrooms often performed better than their peers in traditional settings. Similarly, Caponetto et al. (2018) showed that gamified curricula in biology led to higher test scores, suggesting that gamification's interactive, competitive, and reward-based nature fosters deeper learning and greater motivation.

In this study, the experimental group scored significantly higher on biology tests than the control group. This suggests that using gamified elements, such as points, levels, and challenges, not only engages students but also facilitates better mastery of biological concepts. Huang & Soman (2013) argue that gamification enhances cognitive engagement by providing immediate feedback and reinforcing learning, which likely contributed to the higher academic performance of the experimental group in this study.

b) Increased Student Engagement and Motivation

The results also indicated that students in the gamified learning group showed significantly higher engagement and motivation levels than those in the traditional group. This finding corroborates earlier studies that emphasize the importance of engagement for academic success. Deterding et al. (2011) noted that gamification increases student engagement by incorporating rewards, achievements, and friendly competition, which appeal to students' intrinsic motivation. The increased motivation and interest in the subject observed in this study can be attributed to the fun and interactive nature of gamified learning experiences, which likely made biology lessons more enjoyable and less monotonous for the students.

The self-determination theory (Deci & Ryan, 2000) suggests that gamification can support intrinsic motivation by fulfilling students' autonomy, competence, and relatedness needs. By offering students opportunities to make choices (e.g., earning points or badges) and providing clear challenges and rewards, gamification taps into these psychological needs, fostering greater involvement in learning. As found in this study, when students feel more engaged, they are more likely to invest effort in mastering the content, resulting in improved performance.

c) Improvement in Retention and Understanding of Biological Concepts

The study found that students who participated in gamified lessons demonstrated better retention and understanding of complex biological concepts, such as cellular processes and genetics. This result is consistent with previous research showing that gamification motivates students and leads to better long-term content retention. Gao et al. (2019) found that students in gamified science classrooms performed better in retaining knowledge, especially when the content was presented through interactive and immersive game-like activities. In particular, students in the gamified group in this study retained biological concepts better, which might be explained by the active learning approach encouraged by gamification.

One possible explanation for this improved retention is that gamification promotes active participation in the learning process. Anderson & Rourke (2015) suggest that when students actively engage with the material through game mechanics, they are more likely to internalize and remember the content. In contrast, traditional methods,

which often rely on passive learning through lectures or rote memorization, may not promote the same cognitive engagement and retention level.

Additionally, gamified learning environments often involve repeated practice and continuous feedback, critical for reinforcing concepts. For example, Caponetto et al. (2018) found that quizzes, challenges, and simulations common elements in gamified learning help reinforce students' understanding and retention of scientific concepts.

The findings of this study have important implications for biology education in Nigeria, particularly in the context of senior secondary schools. Biology is a subject that students often find difficult, mainly due to its abstract concepts, such as cellular biology, genetics, and ecology. In Nigeria, where traditional teaching methods such as rote learning dominate, gamification presents an innovative and promising alternative to improve students' understanding and performance in biology.

However, it is essential to consider the challenges of implementing gamification in Nigerian schools. Huang & Soman (2013) highlight that for gamification to be successful, educators must be trained to effectively design and implement game-like activities. Additionally, infrastructure issues such as limited access to technology might hinder the full implementation of gamification in some schools. Nevertheless, Almarashdeh et al. (2018) suggest that even low-tech gamification approaches, such as classroom-based games and quizzes, can effectively improve student engagement and performance. This means that gamification can still be applied in resource-constrained environments, making it a viable solution for Nigerian schools.

The competitive nature of gamification aligns particularly well with the cultural context of Nigerian students, who often place a high value on competition and achievement as key drivers of their academic success. In many Nigerian communities, academic performance is not only a personal achievement but also a source of pride for families and the broader community. Integrating elements such as leaderboards, challenges, and rewards into the learning process, gamification can effectively tap into this cultural emphasis on excelling and outperforming peers. These elements foster a sense of accomplishment and recognition, motivating students to strive for excellence. Furthermore, the element of friendly competition can create a dynamic and engaging classroom atmosphere, where students are encouraged to push their limits, collaborate with others, and work towards mastery, all while reinforcing the educational content interactively and enjoyably. This approach has the potential to transform traditional learning experiences, making education more relatable and enjoyable for Nigerian students.

4. IMPLICATIONS AND CONTRIBUTIONS

4.1 Reseach Implication

The findings of this study suggest several key actions: incorporating gamification into senior secondary biology using simple, low-tech activities that align with learning outcomes; offering structured teacher training (focused on goal setting, selecting points, badges, challenges, and managing large classes) with practical Standard Operating Procedures (SOPs) tailored for schools with limited resources; enhancing school and district policies (regarding time allocation, incentives, and essential materials like mission cards, scoreboards, and feedback sheets) to ensure long-term sustainability; refining assessment methods to evaluate not just end-of-unit scores, but also retention, transfer, collaboration, and scientific attitudes; establishing data-driven monitoring systems (such as pre- and post-tests, engagement rubrics, and student reflections) to support ongoing improvements; ensuring equitable access to gamification to prevent widening achievement gaps between subgroups; and advancing further research on cost-effectiveness, optimal duration and intensity, and factors influencing the scalability of gamification (including motivation, engagement, class size, and teacher experience).

4.2 Reseach Contribution

This study makes several important contributions: (1) providing empirical evidence specific to Delta State, Nigeria, on the effectiveness of gamification in senior secondary biology; (2) using a robust quasi-experimental design with pre- and post-tests, a control group, and delayed retention tests to assess both short- and medium-term effects; (3) developing and adapting locally validated instruments to measure motivation and engagement; (4) proposing a practical, curriculum-aligned, low-tech implementation model with SOPs and teacher training tailored for large, resource-limited classrooms; (5) identifying mediating factors (such as motivation and engagement) and moderating variables (such as class size, teacher experience, and access to devices) that impact academic outcomes; and (6) offering evidence-based policy recommendations to integrate gamification, expand assessment criteria to include retention, transfer, collaboration, and scientific attitudes, and facilitate the broader adoption of gamification across schools.

5. LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

5.1 Reseach Limitations

While the findings of this study are promising, several limitations should be considered. First, the study focused on a specific sample of senior secondary school students in Delta State, Nigeria. The results may not be generalizable to all students across Nigeria or other countries. Future research could replicate this study in different regions and educational contexts to assess the broader applicability of gamification in biology education.

Additionally, the study only examined the short-term impact of gamification on academic performance, engagement, and retention. Longitudinal studies are needed to assess the long-term effects of gamification on students' learning outcomes, particularly as they progress to higher levels of education.

5.2 Recommendations for Future Research Directions

Future research could explore the specific types of gamification elements (e.g., badges, leaderboards, simulations) that most effectively enhance biology learning. Understanding which gamification components have the most significant impact can help educators design more effective and targeted gamified learning experiences.

6. CONCLUSION

This study provides compelling evidence that gamification can substantially enhance academic performance, engagement, motivation, and retention of biological concepts among senior secondary school students in Nigeria. Integrating game-like elements into the learning process makes students more likely to remain engaged and invested in their studies, as they experience a shift from passive learning to active participation. This approach encourages students to deepen their understanding of complex topics and fosters a sense of achievement and progression through rewards and challenges. The findings underscore the potential of gamification to address the traditional challenges faced in biology education, such as low student motivation and difficulty retaining complex content.

Moreover, the results of this study contribute significantly to the expanding body of literature on the effectiveness of gamification as an educational tool. While previous research has explored its benefits in various subjects, this study provides crucial insights into its impact specifically within the context of biology education in Nigeria. As the educational landscape shifts, particularly in response to technological advancements and the increasing demand for interactive learning experiences, gamification presents a promising solution to enhance teaching strategies and improve student outcomes. The findings advocate for the integration of gamification as a key pedagogical approach, especially in subjects traditionally viewed as challenging or less engaging.

Looking ahead, the successful implementation of gamification in the classroom could catalyze a broader transformation in the quality of education in Nigeria and beyond. However, further research and thoughtful, context-specific implementation are essential for gamification's effectiveness. Future studies should explore the long-term effects of gamification, investigate its adaptability across various educational settings, and identify best practices for its integration into different subjects. With careful planning and continuous evaluation, gamification can revolutionize biology education, equipping students with the knowledge and skills necessary to thrive in an increasingly complex and interconnected world.

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Author Contribution Statement

All authors discussed the results, contributed to the final manuscript, and approved the final version for publication. Josephine Ese Konyeme: Conceptualization; Methodology; Formal analysis; Data curation; Writing original draft. Rita Ewere Chukwuka: Investigation (field data collection); Validation; Visualization; Resources and project administration; Writing-review & editing.

Conflict of Interest Statement

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval Statement

The authors declare that this study was conducted with due regard for research ethics, including obtaining approval from the institution. This includes respecting the autonomy of participants, maintaining confidentiality of data, and ensuring their safety and well-being, in accordance with applicable research ethics guidelines.

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