Volume 10 Nomor 1 (2025) Pages 11 – 23
Eduvis : Jurnal Manajemen Pendidikan Islam
Email Journal : eduvis.bbc@gmail.com
Web Journal : http://journal.bungabangsacirebon.ac.id/index.php/eduvis

Design and Evaluation of a Gamified Biology Learning Application for Senior Secondary Students in Ilorin, Nigeria

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Submitted : 2025-06-11 ; Accepted: 2025-07-08 ; Published: 2025-07-09

Abstract

This study examined the Design and Evaluation of a Gamified Biology Learning App for Senior Secondary Students in Ilorin, Nigeria. The problem addressed is the persistent low achievement of students in biology, attributed to traditional teaching methods that fail to engage learners effectively. The objectives were to develop a gamified learning application for selected biology topics, determine its effect on students' academic performance, and examine students' attitudes towards the application. The study adopted a quasi-experimental research design using a pretest-posttest control group approach. A total of 80 senior secondary school students were selected through multistage sampling of SS2 students from two senior secondary school in Ilorin Kwara state, which is make up of the experimental and the control group. Data were collected using a Biology Performance Test (BPT) and an Attitude towards Gamified Learning Questionnaire (AGLQ). Findings revealed that students taught with the gamified application performed significantly better than those taught through traditional methods. Additionally, students demonstrated a positive attitude towards the gamified learning experience. Based on the findings, it is recommended that teachers adopt gamified applications to improve learning outcomes in biology. It is suggested that future studies explore the effects of different gamification elements across various science subjects. In conclusion, the integration of gamified learning applications offers a promising approach to enhancing biology education in Nigerian schools.

Keywords: *Gamified Learning,Biology Education, Educational Technology in Nigeria, Academic Performance, Senior Secondary School Students*

INTRODUCTION

The advancement of Biology underpins the study of other sciences in senior secondary schools and serves as a prerequisite for Medicine, Agriculture, Biotechnology, and Environmental Sciences. Learning Biology is usually perceived as a difficult task because most learners fail to comprehend the abstract nature of the content, the breadth of the material that needs to be covered, and the passive attitude to teaching and learning processes, all combine to enhance negative academic outcomes and attitudes towards the subject. These issues in the Nigerian scenario are made worse as there is a combination of large classes, scant teaching materials, and old-fashioned teacher-dominated practices with no regard to teaching techniques that are tailored to different students (Ajayi, 2018; Adolphus, 2020). As a result, students do not grasp fundamental biological ideas and concepts, leading them to develop an enduring disinterest in the subject.

The proliferation of educational technologies has brought to the fore new instructional approaches such as gamification which refers to the application of game elements such as rewards, competition, and storytelling into instructional activities. Transforming passive learning settings into gamified environments— places where competitions and storytelling invite active participation—is the main premise of gamification. Enhanced engagement with learning through the use of gamified platforms can drive improvements in motivation, participation, and learning results. With learners in the 21st century becoming more digitally inclined, this is becoming more necessary to explore.This research aims to create and assess a gamified learning application designed for the biology curriculum of Nigerian Senior Secondary Schools. In addition to assessing its impact on academic performance, it analyzes how students' attitudes towards biology may shift as a result of interacting with the gamified learning interface. The study is anchored on the need to provide an educational solution that is both appropriate to the local context and pedagogically sound— one that addresses performance gaps while stimulating interest in the biological sciences.

While biology is crucial to developing students' scientific literacy and readiness for various careers, there is a concerning trend of low academic achievement among Nigerians. The biology examinations issued as part of Nigeria's national examinations have persistently pointed to a lack of adequate achievement, failing to meet the expected scholarly standards. Core science subjects consistently present poor results, with biology having one of the highest failure rates. Studies attribute these underperforming academic outcomes to rote learning, lack of hands-on practical engagement, teaching abstract content, and uninspiring instructors (Ige, 2016; Afolabi & Oladejo 2022). In participating in passive learning, students become mere consumers of information, which inevitably leads to their disinterest and poor retention rates.

The problem is made even harder by the fact that students tend to have a negative attitude towards biology. Enthusiasm for science subjects, including biology surrendering to indifference or mild disdain, becomes worse as students advance through secondary school (Tai et al., 2022). The attitude problem is not just affective – it does stem from some frustration, which interacts with academic performance because students who hold these unfavorable perceptions will attempt to learn through materials or content that is far too basic and straightforward, which is actually very difficult (Ndim, 2021). Reversing these trends is possible with emerging technologies. In particular, there is strong evidence that suggests enhancement of engagement and motivation through gamification works via intrinsic and

extrinsic appeal. Gamified methods, however, are still scarce in Nigeria. Where they have been tried, the attempts have been weakened by limited timeframes, small scopes, empirical rigor, and alignment with the curricula. Furthermore, in the local context, the impacts of gamifying learning towards long-term attitude shifts are not yet fully understood.

A fair number of these have focused on the use of gamification in educational settings, and outcomes differ based on context, design, and characteristics of the learners involved.Bello (2019) conducted a longitudinal study with 250 students over two academic sessions. He found that augmented reality (AR) tools increase comprehension and interest in teaching human anatomy. His study showed that students were able to visualize complex structures using gamified AR which contributed to their understanding and sustained attention. Mixed methods and ANOVA analysis was utilized in the study. Murillo et al. (2021) observed that using "escape room" activities in science classes motivated students and increased their engagement. Other studies, however, have more mixed results. Zainuddin et al. (2020) conducted a study on a sample of 150 students and found that although there was an increase in motivation with the use of gamified quizzes, there was no noticeable increase in academic performance. This highlights the importance of game elements being properly aligned with learning objectives. Hanus and Fox (2015) observed that although leaderboards and rewards served as motivators, their impact is often short-lived if there is no substantial learning material to back them up. Kasahara et al. (2019) noted heightened engagement as a result of competitive mechanics, but were concerned about the elevated stress levels among students, particularly in high-pressure situations like programming education.

Ige's (2016) analysis shows a positive correlation between biology gamification and cognitive achievement alongside student motivation. Ajayi (2018) noted increased participation and understanding of complex biology topics such as genetics with the application of game-based teaching methods. This supports the idea that applying game elements enhance both performance and interest in biology education. Equally important is the literature on gender differences in gamified learning. Almasri (2022) reported: female students excelled in collaborative gameplay, while male students did better in competitive activities. Feng et al. (2023) claimed social norms biasing female students observing sensitive subjects, such as reproductive biology, caused discomfort and impacted classroom behavior. Udeani and Akhigbe (2020) demonstrated the usefulness of gamified instruments for both genders' achievement, yet indicated women outperformed men in socially-based situations. Almusharraf et al. (2023) described similar tendencies, stating that women prefer competing in teams while men prefer competing individually.

In contrast, Nguyen et al. (2022) noted that male students engaged more in gamified competitive tasks related to speed and problem-solving.According to Zahedi et al. (2021), storytelling made narrative-based games more effective for female learners than males, whereas Yang et al. (2014) showed that males performed better in more spatially demanding simulations. Thaddeus (2021) and Tsai (2017), however, found no significant differences between males and females when gendered bias was effectively removed and gamification was incorporated, indicating that properly designed gamified applications may equalize disparities in academic performance across genders. Musengimana et al. (2021) found that girls had a more favorable attitude towards biology compared to chemistry or physics. This contrasts with Ross (2023), who reported that human biology topics were more popular among Australian schoolgirls than their male counterparts. Prokop (2007) and Adolphus (2020) remarked that

teaching methods and age impact students' attitudes, especially young females who show interest in biology when taught using engaging instructional methods.

Khoshnoodifar et al. (2023) and Alsadoon et al. (2022) showed that the implementation of gamified learning increased motivation and attitude among students. Students with access to gamified materials showed enhanced self-efficacy, retention, and participation. In addition, Pettit et al. (2015) reported that discipline and a sense of community within the class improved in a gamified setting. While Ahmad et al. (2022) reported no notable variances between genders regarding attitudes towards biology, Ndim (2021) has pointed out the salient relationship between favorable attitudes and strong performance.Some studies are brief and focus on a singular aspect and are not situated within frameworks like Bartle's Taxonomy of Player Types, the Octalysis Framework (Deterding, 2011), or the Self-Determination Theory (Deci & Ryan, 2000). There is also a minimal focus on providing practical strategies for the application of gamified learning into traditional curriculum structures. Ali and Mohammed (2023) have argued that the lack of proper training for teachers inhibits the optimal application of educational technologies, highlighting the need for professional advancement initiatives in association with modern technologies.

Addressing the gap in literature motivates this study, therefore, the incorporation of a learning achievement mechanism through a graded biology gamified application will be used to enhance performance and, at the same time, change students' attitudes toward biology positively.Evaluate the impact of a context-specific digital tool on the cognitive and affective domains, targeting senior secondary school students set in Kwara state, Nigeria.

Purpose of the Study

The main purpose of this study is to design, and evaluate Gamified learning app on senior secondary school students' performance in biology in Ilorin. Specifically, this study will seek to:

3. Implement the gamified application in a quasi-experimental setup to determine its effect on students' performance in biology.
4. Compare the pre-test and post-test performance of students exposed to the gamified application (experimental group) and those taught using traditional methods (control group).
5. Investigate students' attitudes towards using the gamified application for learning biology.

Research Questions

The study shall provide answers to the following research questions:

1. What is the effect of the gamified application on the performance of senior secondary school students in biology, as measured by the difference between their pre-test and post-test scores?
2. How does the post-test performance of students taught using the gamified application compare to that of students taught using traditional methods in biology?
3. What are the attitudes of senior secondary school students towards the use of the gamified learning application for biology?

Research Hypotheses

The following hypotheses were raised and will be tested in the study:

$H0_1$: There is no significant difference between the pre-test and post-test scores of students taught using the gamified application in biology.

$H0_2$: There is no significant difference in the post-test performance of students in the experimental group and those in the control group in biology.

$H0_3$: There is no significant difference in students' attitudes towards the use of the gamified application for learning biology.

METHODOLOGY

In order to assess the impact of gamified learning on students' academic performance in biology, the study used a quasi-experimental pre-test/post-test control group design with a factorial structure. Purposively choosing two intact classes of SSS 2 students from Ilorin, Kwara State School A (control group) has 40 students, and School B (experimental group) has 36 students to serve as the experimental and control cohorts reduced bias by sourcing participants from various institutions. While the control group got traditional training, the experimental group used a gamified learning application.

Pre-tests and post-tests were used to gather data, along with a thorough lesson plan that matched the curriculum's musculoskeletal system subjects. Expert assessments in the domains of science education and educational technology were used to verify the validity of the instrument, and a pilot study using Cronbach's alpha coefficient was used to confirm its reliability. Participants' informed permission was obtained, and ethical approval was acquired. Academic performance improvements were evaluated using pre-test and post-test scores, and qualitative viewpoints were obtained via attitudinal replies. Six weeks were allotted for data gathering, and protocols were created to ensure uniformity, privacy, and rigorous adherence to ethical research guidelines. IBM SPSS (Statistical Package for the Social Sciences) version 23.0 will be used to analyze the collected data using descriptive and inferential statistical techniques. While independent t-tests at a 0.05 level of significance will assess research hypotheses and identify differences in student performance and attitudes based on study variables, frequencies, percentages, means, and standard deviations will be utilized to summarize demographic data and respond to research questions.

RESULTS

Research Question 1: What is the effect of the gamified application on the performance of senior secondary school students in biology, as measured by the difference between their pre-test and post-test scores?

Table 1.
Difference Between Pre-Test And Post-Test Performace of Senior Secondary School Students

Group	N	Mean Pre-test ($\bar{X}$)	SD (Pre-test)	Mean Post-test ($\bar{X}$)	SD (Post-test)	Mean Gain	% Effect
Experimental	36	46.48	7.37	76.71	9.75	30.19	64.99%
Control	40	45.66	7.43	59.65	6.67	13.99	35.01%

The effects of the gamified application on biology students' performance are shown in Table 1. The pre-test mean score for the experimental group, which utilized the gamified program, was 46.48 with a standard deviation of 7.37. Their post-test mean score rose to 76.71 with a standard deviation of 9.75 following the use of the gamified learning strategy, indicating a mean gain of 30.19 and a 64.99% percentage effect. On the other hand, the control group, which received instruction by conventional means, had a mean score of 45.66 on the pre-test with a standard deviation of 7.43, and a mean score of 59.65 with a standard deviation of 6.67 on the post-test. This led to a 35.01% percentage effect and an average gain of 13.99. These findings suggest that students who used the gamified learning application showed a significantly higher improvement in their performance compared to those who were taught using traditional methods.

Research Question 2: How does the post-test performance of students taught using the gamified application compare to that of students taught using traditional methods in biology?

Table 2.
Mean and Standard Deviation of Post-Test Performance of Students Taught Using the Gamified Application Compare to That of Students Taught Using Traditional Methods in Biology

Group	N	Mean Post-test ($\bar{X}$)	SD (Post-test)
Experimental	36	76.71	9.75
Control	40	59.65	6.67

A comparison of the experimental and control groups' post-test results is shown in Table 2. The mean post-test score for students who received instruction using the gamified application was 76.71 with a standard deviation of 9.75, whereas the mean score for students who received instruction through conventional techniques was 59.65 with a standard deviation of 6.67. This suggests that pupils who used the gamified program outperformed those who received instruction through traditional means.

Research Question 3: What are the attitudes of senior secondary school students towards the use of the gamified learning application for biology?

Table 3.
Mean and Standard Deviation of Students' Attitudes Towards the Gamified Learning Application

S/No	ITEMS	Mean	Standard Deviation
1	Learning using Gamified learning app motivates and catches my attention	3.09	0.93
2	Every expectations I have for this lesson has being achieved	2.99	0.97
3	I am eager to take more subjects through the use of Gamified learning app	3.11	1.00
4	I find the content of this lesson interesting	3.19	0.88
5	The Gamified learning app gives me enormous opportunity for learning	3.07	0.95
6	I feel more comfortable using the Gamified learning app for learning	3.06	0.99
7	The Gamified learning app assists me to learn and progress at my own pace	3.14	0.91
8	Gamified learning app has influenced my academic performance in Biology	3.09	0.93
9	The contents in the lessons have met the standard compared to textbooks	3.04	0.98
10	The Gamified learning app provides varieties of contents that help in concentration and longtime retention	3.11	1.01

Students' opinions on using the gamified biology learning software are shown in Table 3. Each item's mean score falls between 2.99 and 3.19, suggesting that the gamified learning application is generally viewed favorably. With a mean score of 3.09 and a standard deviation of 0.93, students concurred that the gamified learning app engaged and inspired them. A mean score of 2.99 and a standard deviation of 0.97 indicate that they likewise thought the instruction met their expectations. Additionally, students considered the lesson content fascinating (mean = 3.19, SD = 0.88) and reported a desire to take more topics using the gamified application (mean = 3.11, SD = 1.00). Additionally, students acknowledged that the gamified application provided opportunities for learning at their own pace and enhanced their academic performance in biology. Overall, these responses suggest a favorable attitude towards the use of gamified learning in biology.

Hypotheses Testing

The result of all hypotheses testing in this study are represented in presentation table with interpretations respectively , All hypotheses were analysed using t-test at significant level of 0.05

Ho1: There is no significant difference between the pre-test and post-test scores of students taught using the gamified application in biology.

Table 4.
t-test Analysis of Significant Difference Between the Pre-Test And Post-Test Scores of Students Taught Using the Gamified Application in Biology

Variables	No	X	SD	Df	T	Sig (2tailed)	Decision
Pre- test	36	46.48	7.37				
				37	15.56	0.023	Rejected
Post-test	40	76.71	9.75				

The t-test analysis comparing the pre-test and post-test results of students who were taught biology using the gamified application is shown in Table 4. According to the findings, the average score before the exam was 46.48 with a standard deviation of 7.37, and the average score after the test was 76.71 with a standard deviation of 9.75. The significance threshold was set at 0.023, and the computed t-value was 15.56. The null hypothesis was rejected since this result was below the significance level of 0.05. This suggests that the gamified learning application was successful in improving learning outcomes since students' performance significantly improved after using it.

Ho2: There is no significant difference in the post-test performance of students in the experimental group and those in the control group in biology.

Table 5.
T-Test Analysis of Significant Difference in the Post-Test Performance of Students in the Experimental Group and Those in the Control Group In Biology

Group	No	X	SD	Df	T	Sig (2tailed)	Decision
Experimental	36	76.71	9.75				
				74	9.12	0.000	Rejected
Control	40	59.65	6.67				

The post-test results for the experimental and control groups are contrasted in Table 5. The control group scored 59.65 with a standard deviation of 6.67, whereas the experimental group, which utilized the gamified program, scored 76.71 with a standard deviation of 9.75. The significance threshold was 0.000, which is less than 0.05, and the computed t-value was 9.12. Because of this, the null hypothesis was rejected, showing that students who utilized the gamified program outperformed those who received instruction through conventional means**.**

H_{O3}: There is no significant difference in students' attitudes towards the use of the gamified application for learning biology.

Table 6.
T-Test Analysis of Significant Differencei Students' Attitudes Towards the use of the Gamified Application for Learning Biology

Variables	No	X	SD	Df	T	Sig (2tailed)	Decision
Attitude Mean Score	36	3.09	0.95	34	17.44	0.001	Rejected

The t-test study of students' opinions about the use of the gamified biology learning application is shown in Table 6. With a standard deviation of 0.95, the average score for students' attitudes was 3.09. The significance threshold was set at 0.001, and the computed t-value was 17.44. The null hypothesis was rejected as the significance value fell below the 0.05 cutoff. This finding suggests that students' attitudes regarding using the gamified biology learning application were statistically significantly positive. Thus, it can be said that students showed a positive attitude regarding using the gamified platform to learn biology.

Discussion of Findings

The study designed and assessed a biology gamified learning application in an attempt to improve attitude and performance for senior secondary school students in Ilorin, Nigeria. It was established that there was considerable improvement in students' academic performance as well as their attitude toward learning biology through gamification. The discussion of findings is organized based on the causative research questions and hypotheses of the study.

The impact of the gamified application on students' performance, shows that there was improvement. Students that utilized the gamified learning application had an average gain of 30.23 (64.99%) from their pre-test and post-test scores, while the control group whose teaching was traditional had a mean gain of 13.99 (35.01%). These results are consistent with other scholars who noted the impact of gamification on cognitive achievement-Ige (2016) and Bello (2019). It can be assumed that attributes of gamification like rewards, feedback, and interactivity brought about higher levels of participation which subsequently improved understanding and retention of biological concepts (Murillo et al., 2021). These findings support Deci and Ryan (2000) in their Self-Determination Theory, which emphasizes that intrinsic motivation stemming from autonomy and competence is vital for effective learning. Thus, the study verifies the assumption that appropriately designed gamified interventions can significantly improve learning proficiency in science education.

Research question two addressed the change in post-test scores of the experimental group that utilized the gamified application relative to those taught using traditional methods. The findings indicated that learners in the experimental group performed better than the control group, achieving higher mean post-test scores (M = 76.71, SD = 9.75) than the control group's average (M = 59.65, SD = 6.67). This suggests that, contrary to traditional teaching approaches, the gamified application enhanced academic achievement more than the other methods, in agreement with Ajayi (2018) and Adolphus (2020) who called for the use of digital teaching

aids in the teaching of science. In particular, the features of the gamified application might have promoted active participation and knowledge creation, overcoming the shortcomings posed by the lecture method of teaching (Hanus & Fox, 2015). Moreover, this result supports Kasahara et al. (2019) who assertion that appropriately designed gamified environments enhance both engagement and academic achievement when aligned with curriculum objectives.

The results showed that students had a generally good opinion of the gamified application, which addressed the third study question. Students were motivated, considered the learning material interesting, and showed excitement for further gamified learning experiences, according to the mean scores across attitude questions, which varied from 2.99 to 3.19. The findings of Khoshnoodifar et al. (2023) and Alsadoon et al. (2022), who discovered that gamified learning environments greatly improve learners' attitudes and motivation, are corroborated by this outcome. This favorable attitude was probably influenced by the application's capacity to offer immediate feedback, chances for self-paced learning, and components of competition and teamwork (Almasri, 2022). Furthermore, the results support the claim made by Pettit et al. (2015) that gamification enhances topic mastery and fosters supportive learning environments that support long-term academic interest.

The first hypothesis examined if the pre-test and post-test results of students who were taught using the gamified application differed significantly. The null hypothesis was rejected based on the t-test results ($t = 15.56$, $p = 0.023$), which showed a statistically significant improvement. This result supports findings from other research, like Bello (2019) and Ige (2016), which show that gamified tools promote significant learning improvements. The considerable improvement in post-test scores offers further support of the gamified application's capacity to solve the learning obstacles associated with complicated and abstract biology subjects.

Additionally, it supports the idea that interactive and captivating teaching methods are essential for raising student achievement in secondary schools in Nigeria (Afolabi & Oladejo, 2022).

The second hypothesis investigated whether the experimental and control groups' post-test results differed significantly. Students who utilized the gamified program did better than those who got traditional teaching, according to the t-test findings ($t = 9.12$, $p = 0.000$). When compared to teacher-centered methods, the gamified platform's efficacy is demonstrated by the null hypothesis' rejection.This discovery supports Ajayi (2018) and Zainuddin et al. (2020), who posited that the incorporation of game elements into educational content can assist in bridging the gap between knowing and doing. It also incorporates Bartle's (1996) player types taxonomy which indicates that gamified instruction promotes engagement from all learner types—achievers, explorers, socializers, and killers—thereby enhancing participation and learning outcomes.

The third hypothesis focused on students' perceptions regarding gamified learning. The analysis gave a t-value of 17.44 with a p-value of 0.001 which indicates that the null hypothesis was disproven. This outcome signifies that students had a perceivable positive attitude towards the use of the gamified application. This result was also found by Musengimana et al. (2021) and Ross (2023), where a positive attitude towards scientific subjects was related to better academic performance. The positive attitude toward the gamified application suggests that digital devices, when properly contextualized to the culture and needs of the learners, can effectively transform the perception of science education in Nigeria (Ali & Mohammed, 2023).

Recommendations

1. To improve students' academic performance, biology professors should include gamified learning tools into their lessons.
2. Schools ought to spend money creating and implementing gamified teaching resources for biology and other science courses.
3. As part of senior high school biology teaching methodologies, curriculum planners want to incorporate gamified exercises.
4. Training programs and seminars should be provided for instructors to equip them with skills to create and effectively execute gamified learning environments.
5. By offering incentives and policies that support technology-based teaching approaches, educational officials should promote the usage of gamified apps.

In order to boost their children's academic performance and interest in biology, parents and guardians can encourage them to adopt educational technology, such as gamified applications.

Suggestions for Further Studies

1. Beyond the immediate post-test results, future studies should look at how gamified applications affect students' long-term recall and comprehension of biological subjects.
2. Additional research can examine how well various gamification techniques (such challenges, prizes, or narrative) affect biology students' academic achievement.
3. To find subject-specific benefits, researchers could investigate how students feel about gamified learning in physics, chemistry, and other science courses. Future studies should examine how students' unique learning preferences affect how well gamified biology learning applications work.

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