International Journal of Spectrum Research in Education & Humanities (IJSREH)
1(3), July-September, 2025, Pages 22-32

ISSN: 3092-9539

https://doi.org/10.5281/zenodo.16359215

Evaluating the Effect of Gamification-Based Approach in Teaching Complex Concepts in Biology

Jane Nwakaego Achufusi Ph.D

Department of Biology, Nwafor Orizu College of Education, Nsugbe
Anambra State, Nigeria.
jachufusi@Gmail.Com

ABSTRACT

This study assessed the effectiveness of a gamification-based approach in teaching complex biology concepts to senior secondary Biology students. The study was addressed by three research questions and three hypotheses test for significant differences in achievement scores across teaching methods and gender groups. The study used a quasi-experimental design with a pre-test, post-test control group approach, involving 100 students randomly assigned to two groups of fifty each: one group taught with traditional lecture methods and the other using gamification. The six-week study focused on "Energy Transformation in Nature" and covered sub topics such as energy loss in ecosystem, laws of thermodynamics, application of laws to ecological phenomena, food chain. The experimental group engaged with a gamified learning module, earning rewards for tasks, while the control group received traditional lecture-based instruction. The Biology Achievement Test (BAT), validated for SS1 students, measured pre-test and post-test performance. Data collected were analyzed using descriptive and inferential statistics. The results showed that the gamification-based approach significantly improved student understanding of complex biological concepts, with higher post-test scores compared to the lecture method group. The findings suggest that gamification can be an effective tool in enhancing student engagement and comprehension, particularly in challenging subjects like biology. The study recommends incorporating gamification into teaching practices to foster interactive learning and better conceptual grasp among students.

Keywords: Gamification, biology education, complex concepts, teaching methods, student engagement

INTRODUCTION

Biology is a subject that many senior secondary school students in Nigeria find both fascinating and challenging. Biology is not only important for students who want to go into fields like medicine, nursing, or agriculture, but it also helps young people understand the world around them in a more meaningful way (Enyinnaya et al, 2025). In Nigerian secondary schools, biology is a compulsory subject for science students. However, teaching it effectively is not always easy. Many schools struggle with outdated textbooks, lack of laboratory equipment, and large class sizes that make hands-on learning difficult. This often makes it hard for students to grasp some of the more complex topics like genetics, ecology, or the human body systems (Abidoye, 2024). When it comes to teaching certain complex topics especially in the area of ecology and the environment, both teachers and students often encounter serious challenges. Concepts like energy loss in ecosystems, the laws of thermodynamics, their ecological applications, and food chains tend to be abstract and difficult to grasp through traditional teaching methods (Ekon *et al*, 2024). This is where gamification can make a huge difference.

Gamification is the use of game-like elements such as points, rewards, levels, and challenges in non-game settings like the classroom to boost student engagement and motivation (Khan *et al*, 2017). Instead of just reading from textbooks or listening to long lectures, students get to interact

with the lesson in a more playful and exciting way. This method keeps them motivated, helps them focus better, and often makes even tough topics easier to understand. Teachers can use gamification in different ways, like through educational games, quizzes, story-based adventures, or digital apps, where students earn points and badges as they learn (Ahmed *et al*, 2025). It can be helpful in subjects like biology, where some ideas can feel abstract or hard to relate to. When students are part of the learning process, making decisions and solving problems like in a game, the knowledge sticks better. Increasingly, research supports the idea that when students are immersed in game-based environments, their motivation, curiosity, and comprehension of complex concepts improve dramatically (Nyaaba *et al*, 2024).

One of the core ideas in ecology is that energy is lost as it flows through different trophic levels in an ecosystem. Students often struggle to understand why, for example, only about 10% of energy is transferred from one level to the next, and the rest is lost through heat and metabolic processes (Olasehinde & Olatoye, 2014). Instead of just telling students this through diagrams or textbook paragraphs, gamified approaches give them the chance to experience it. For instance, role-playing games where students act as producers, herbivores, or carnivores can simulate real-life energy transfers. Through such games, students can observe firsthand, how energy diminishes as it moves through the system. Attah *et al* (2024), found that interactive, game-based environments help students visualize abstract ideas, leading to deeper learning and better retention.

The first and second laws of thermodynamics—conservation of energy and increase in entropy—are central to understanding how ecosystems work. Yet, these laws often feel like they belong more in physics than in biology; making them tough for students to relate to ecological systems (Diyoke & Ngwaka, 2025). Gamification helps bridge this gap by offering simulations that make these laws visible and tangible. Imagine students using a digital ecosystem to experiment with energy inputs and observe the results. Understanding thermodynamics is one thing—applying it to real-world ecological scenarios like food webs, productivity, or ecosystem sustainability, is another. This application requires critical thinking and the ability to make connections across different scientific domains. Gamification makes this easier by simulating real-life situations. Eyube *et al* (2025), emphasized that such games build not just content knowledge, but also problem-solving and analytical skills—key competencies in scientific education today.

Food chains are foundational in ecology, but they come with their own complexities. It is one thing to know that grass is eaten by a rabbit, which is then eaten by a fox, but it is another thing entirely to understand how energy, matter, and population dynamics are all tied together (Birol *et al*, 2023). With gamified tools like card games, interactive simulations, or even mobile apps, students can build and manipulate food chains themselves. They can remove or add species and see how this affects the entire ecosystem. Salimon *et al*, (2021), found that this kind of gamification encourages deeper engagement because it places students in control of the learning process. When they see a digital forest collapse because they removed one keystone species, the lesson sticks with them.

Research has shown that gamification can help students not only understand biology better but also enjoy the learning process more. Instead of passively receiving information, they explore, make decisions, and reflect on the outcomes. This shift from traditional, didactic methods to game-based learning according to Ogbu (2025), transforms the classroom into a dynamic environment where students feel more ownership of their learning journey. Therefore, motivation for this study stems from the persistent difficulty students face in understanding complex biology concepts, particularly in areas like ecology and environmental science. Concepts such as energy loss in ecosystems, the laws of thermodynamics, and the application of these laws to ecological phenomena are often abstract and challenging to visualize. Traditional teaching methods, which rely heavily on chalk-and-board instruction, have been found to be insufficient in fostering deep understanding and long-term retention (Nyaaba *et al*, 2024).

Moreover, studies show that student engagement and achievement in biology have been declining, especially when the content becomes technical or abstract (Ekon *et al.* 2024). While innovative methods such as computer simulations and multimedia tools have been introduced, they

are often expensive and not readily available in many Nigerian schools (Wu, 2024). This creates a significant gap in making science education more learner-centered and accessible. Gamification, with its promise of turning learning into an active, rewarding experience, presents a practical alternative. However, despite its growing use globally, there is limited empirical evidence on its effectiveness in Nigerian secondary school biology classrooms. This study, therefore, seeks to fill this gap by exploring how gamification can be used to simplify and enhance the teaching of difficult biology topics.

Research Questions

1. What are the mean achievement scores and standard deviation of students taught Complex concepts in biology with gamification-based approach and lecture methods?
2. What are the mean achievement scores and standard deviation of male and female students taught Complex concepts in biology with lecture method?
3. What are the mean achievement scores and standard deviations of male and female students taught Complex concepts in biology with gamification-based approach methods?

Research Hypotheses

1. There is no significant difference in the mean achievement scores and standard deviation of students taught Complex concepts in biology with lecture and gamification-based approach methods
2. There is no significant difference in the mean achievement scores of male and female students taught Complex concepts in biology with lecture method
3. There is no significant difference in the mean achievement scores and standard deviation of male and female students taught Complex concepts in biology with gamification-based approach method

LITERATURE REVIEW

The gamification-based approach has gained momentum in educational research as an innovative strategy for enhancing the comprehension of complex concepts, particularly in resource-constrained or conventional classroom environments. An extensive analysis of literature shows that gamification fosters deeper cognitive engagement, improves motivation, and positively impacts learners' academic performance. This is achieved through the incorporation of game elements—such as rewards, levels, competition, feedback loops, and storytelling—into teaching and learning processes. A number of scholars have explored the pedagogical potential of gamification in simplifying complex content. Gkintoni *et al* (2024), observed that gamification supports cognitive restructuring, allowing students to construct new knowledge by engaging interactively with difficult concepts. In their experimental study among biology students, the authors noted that integrating game mechanics such as points and challenges led to increased curiosity and willingness to engage with difficult topics like genetics and cell biology, which are often perceived as abstract.

Similarly, Adeoye (2023), emphasized that the visual and problem-solving elements embedded in gamified learning align with multiple intelligences and learning styles. They demonstrated that gamified simulations helped students develop a more intuitive understanding of scientific processes in physics and chemistry, particularly through virtual experiments. Their study revealed a significant correlation between game-based instruction and students' ability to solve higher-order questions, suggesting that gamification also supports the development of critical thinking skills. Adegun and Adegun (2013), extended this discussion by focusing on mathematics education, a subject widely regarded as complex by Nigerian students. Their study found that learners exposed to gamified environments outperformed those in traditional classrooms in areas like algebra and calculus. The structured, yet flexible nature of gamified platforms, allowed learners

to progress at their own pace, with immediate feedback; helping them self-correct and internalize difficult concepts.

The motivational aspect of gamification has also been a central theme in the literature. Oke *et al*(2023), highlighted that gamification transforms the learning experience into a more rewarding journey by integrating progressive milestones, competition, and recognition systems. These features foster intrinsic motivation, reduce learner anxiety, and create a more student-centered classroom culture. The scholars argued that this transformation is especially beneficial in Nigerian classrooms where rigid pedagogical practices often discourage learner autonomy and creativity. Despite these positive findings, some studies also point to challenges and contextual limitations. Ogbu (2025), argued that the overemphasis on competition in some gamified settings could be counterproductive, especially for low-performing students. They cautioned that poorly designed gamification might widen performance gaps, if not implemented with sensitivity to students' diverse abilities. Additionally, the lack of adequate digital infrastructure and limited professional development for teachers in gamification practices hinder effective adoption in many Nigerian schools.

RESEARCH METHOD

The study employed a quasi-experimental design with a pre-test, post-test control group approach, involving a total of 100 students. These students were randomly assigned to two groups: one taught using traditional lecture methods, and the other, using gamification techniques. The study took place over six weeks, with each lesson lasting 80 minutes and focused on the topic "Energy Transformation in Nature." The sub-topics covered included energy loss in ecosystems, laws of thermodynamics, their application to ecological phenomena, and the food chain.

The experimental group participated in an interactive, gamified learning module designed to engage them with the lesson content through game-like elements such as points, badges, and leaderboards. Students earned rewards for completing tasks, answering questions, and solving challenges, all aimed at reinforcing biological concepts in a more dynamic and engaging way. In contrast, the control group received traditional lecture-based instruction, where the teacher presented the material through direct teaching, with students participating in discussions and note-taking.

To assess the students' knowledge before and after the lessons, the study used the Biology Achievement Test (BAT), which included both multiple-choice and short-answer questions. The BAT was carefully developed to measure students' understanding of the content taught during the lessons. It was validated by subject matter experts and reviewed by biology teachers to ensure that it was appropriate for the SS1 level and aligned with the study's objectives. The gamification module was also validated, the reliability of the test instrument has already been established to ensure it was suitable for teaching complex biology concepts in an interactive way. Both the test and the module showed strong reliability, with Cronbach’s Alpha scores of 0.85 and 0.82, respectively.

The teaching took place over a six-week period, and each lesson was structured to last 80 minutes, split into two periods. While both groups were taught the same material, the experimental group interacted with the content in a much more engaging manner through the gamified approach. The pre-test was administered to all students at the beginning of the study to gauge their initial understanding of the topic. After the lessons, the post-test was given to measure the knowledge gained by the students. Data collected from both the pre-test and post-test were analyzed using descriptive statistics, such as means and standard deviations, and inferential statistics, including independent samples t-tests, to compare the differences in performance between the groups. Ethical considerations were also taken seriously, ensuring that all students were fully informed about the study’s purpose. Participation was voluntary, and students were free to withdraw from the study at any time without penalty.

RESULTS AND DISCUSSION

Research Question One: What are the mean achievement scores and standard deviation of students taught Complex concepts in biology with lecture and gamification-based approach methods?

Table 1: Comparative Descriptive Statistics of Pre-test and Post-test Scoresof students taught Complex concepts in biology with lecture and gamification-based approach methods**.**

Measure	Control Group (Lecture Method)		Experimental Group (Gamification Approach)		Total	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Mean	26.36	44.74	26.00	59.16	26.18	51.95
N	50	50	50	50	100	100
Std. Deviation	14.252	16.208	14.301	21.281	14.206	20.166
Variance	203.133	262.686	204.531	452.872	201.806	406.674
Kurtosis	-0.346	-0.667	5.026	-0.594	2.153	-0.419
Skewness	0.929	0.003	1.864	-0.049	1.377	0.226

Table 1 presents the comparative descriptive statistics of the pre-test and post-test scores of students taught complex biology concepts using lecture and gamification-based approaches. For the control group, the mean pre-test score was (26.36), which increased to (44.74) after the post-test. In contrast, the experimental group showed a higher improvement, with the pre-test mean score at (26.00) and post-test at (59.16). Overall, the total group had a pre-test mean of (26.18) and a post-test mean of (51.95). The experimental group had a larger standard deviation in both pre-test (14.301) and post-test (21.281), indicating more variation in scores.

Research Question 2: What are the mean achievement scores and standard deviation of male and female students taught Complex concepts in biology with lecture method?

Table 2:Descriptive Statistics for Pre-test and Post-test Scores by Gender in Lecture Method Group

Statistic	Male		Female		Total	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Mean	27.14	65.41	23.61	52.75	25.16	58.32
N	22	22	28	28	50	50
Std. Deviation	14.334	18.215	9.287	17.208	11.777	18.592
Variance	205.457	331.777	86.247	296.120	138.709	345.651
Kurtosis	0.811	-0.496	-0.331	-0.559	1.543	-0.472
Skewness	1.153	-0.215	0.343	-0.220	1.126	-0.117

Table 2 presents the descriptive statistics for the pre-test and post-test scores by gender in the lecture method group. The male students had a mean pre-test score of (27.14) and a significant increase to (65.41) in the post-test. Female students had a lower pre-test mean of (23.61), with an increase to (52.75) in the post-test. The overall group had a pre-test mean of (25.16) and a post-test mean of (58.32). The standard deviation was higher for males in both the pre-test (14.334) and post-test (18.215), indicating more score variability. Female students showed less variability, particularly in the pre-test, with a standard deviation of (9.287).

Research Question 3: What are the mean achievement scores and standard deviations of male and female students taught Complex concepts in biology with gamification-based approach methods?

Table 3:Descriptive Statistics for Pre-test and Post-test Scores by Gender in Gamification-Based Approach Group

Statistic	Male		Female		Total	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**
Mean	28.73	44.91	24.21	43.57	26.20	44.16
N	22	22	28	28	50	50
Std. Deviation	15.929	14.034	12.662	16.721	14.220	15.457
Variance	253.732	196.944	160.323	279.587	202.204	238.913
Kurtosis	-1.309	-0.922	0.895	-1.502	-0.472	-1.296
Skewness	0.580	-0.496	1.262	-0.107	0.915	-0.246

Table 3 illustrates the descriptive statistics for the pre-test and post-test scores of male and female students in the gamification-based approach group. Male students had a mean pre-test score of (28.73), which rose to (44.91) in the post-test. Female students began with a mean pre-test score of (24.21), improving to (43.57) in the post-test. The pre-test mean for the entire group was (26.20), while the post-test mean was (44.16). The male students showed a higher standard deviation in the pre-test (15.929), which decreased in the post-test (14.034). Female students had a higher standard deviation in the post-test (16.721).

Research Hypothesis 1: There is no significant difference in the mean achievement scores and standard deviation of students taught Complex concepts in biology with lecture and gamification-based approach methods.

Table 4: Independent Samples t-Test Comparing Pre-test and Post-test Scores of Students Taught Biology Using Lecture and Gamification-Based Methods

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pre-test	Equal variances assumed	.773	.381	.126	98	.900	.360	2.855	-5.306	6.026
	Equal variances not assumed			.126	97.999	.900	.360	2.855	-5.306	6.026
Post-test	Equal variances assumed	3.103	.081	-3.812	98	.000	-14.420	3.783	-21.927	-6.913

	Equal variances not assumed		-3.812	91.534	.000	-14.420	3.783	-21.934	-6.906

The pre-test results in Table 4 showed no significant difference in achievement scores between the lecture and gamification-based groups (t(98) = 0.126, p = 0.900). However, in the post-test, there was a statistically significant difference (t(98) = -3.812, p = 0.000), with students in the gamification-based method group performing better. The mean difference was (-14.420), indicating higher achievement under the gamification method. The confidence interval [-21.927, -6.913] confirms this effect. Therefore, Research Hypothesis 1 is rejected for post-test scores, suggesting the gamification-based approach significantly improved student achievement in biology.

Research Hypothesis 2: There is no significant difference in the mean achievement scores of male and female students taught Complex concepts in biology with lecture method

Table 5: Independent Samples t-Test Comparing Post-Test Scores of Male and Female Students

Taught Biology Using the Lecture Method

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pre-test	Equal variances assumed	3.705	.060	1.053	48	.298	3.529	3.352	-3.210	10.268
	Equal variances not assumed			1.001	34.240	.324	3.529	3.524	-3.631	10.689
Post-test	Equal variances assumed	.002	.963	2.517	48	.015	12.659	5.030	2.545	22.773
	Equal variances not assumed			2.499	43.965	.016	12.659	5.065	2.451	22.868

For Research Hypothesis 2, the pre-test results in Table 5 show no significant difference between male and female students (t(48) = 1.053, p = 0.298), meaning the hypothesis is accepted for the pre-test. However, in the post-test, there is a significant difference (t(48) = 2.517, p = 0.015), with male and female students showing different achievement levels. The mean difference of (12.659) suggests better performance from one gender. Thus, Research Hypothesis 2 is rejected for post-test scores, indicating a significant gender difference in achievement when taught with the lecture method.

Research Hypothesis 3: There is no significant difference in the mean achievement scores and standard deviation of male and female students taught Complex concepts in biology with gamification-based approach method

Table 6: Independent Samples t-Test Comparing Post-Test Scores of Male and Female Students Taught Biology Using Gamification-Based Approach

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Pre-test	Equal variances assumed	3.504	.067	1.117	48	.270	4.513	4.041	-3.612	12.638
	Equal variances not assumed			1.086	39.462	.284	4.513	4.154	-3.887	12.913
Post-test	Equal variances assumed	2.748	.104	.301	48	.765	1.338	4.445	-7.600	10.275
	Equal variances not assumed			.307	47.759	.760	1.338	4.352	-7.413	10.088

For Research Hypothesis 3, the pre-test results in Table 6 show no significant difference between male and female students ($t(48) = 1.117$, $p = 0.270$), meaning the hypothesis is accepted for the pre-test. Similarly, the post-test results show no significant difference ($t(48) = 0.301$, $p = 0.765$), indicating that gender did not significantly affect student achievement under the gamification-based method. Since the p-values for both tests are greater than 0.05, Research Hypothesis 3 is accepted, suggesting no significant gender differences in achievement for the gamification-based approach.

Discussion of Findings

The study aimed to compare the achievement scores and standard deviations of students taught complex biology concepts using two different teaching methods—lecture-based and gamification-based approaches. Research question one examined the difference in mean achievement scores and standard deviations between the two groups. The findings showed that while both methods led to improvements in students' performance, however, the gamification-based approach resulted in a more significant increase in scores. The experimental group demonstrated a higher level of variation in scores, suggesting that the gamified method was more engaging, though it also created more diverse student outcomes. This aligns with other studies that highlight the effectiveness of gamification in improving academic performance, as it increases student engagement and motivation (Ahmed *et al,* 2025). In contrast, the lecture method resulted in less variation in scores, which is consistent with research suggesting that traditional methods struggle to engage students fully (*Nyaaba et al,* 2024). The gamification approach, therefore, appears to provide more interactive and stimulating learning experiences, making it a more effective method for teaching complex concepts in biology.

Research question two explored the achievement scores and standard deviations by gender for students taught using the lecture method. Male students had a higher pre-test score compared

to females, and both genders showed significant improvement. The findings also revealed that male students exhibited more variability in scores, which suggests that the lecture method had a greater impact on them. Female students, on the other hand, showed more consistency in their scores, especially in the pre-test. These gender differences are consistent with other studies that report males generally outperform females in traditional educational settings, possibly due to the more structured nature of such methods (Olasehinde & Olatoye, 2014). In contrast, research indicates that gamification-based methods have the potential to minimize gender disparities in learning outcomes by offering more personalized and engaging learning experiences (Attah *et al*, 2024). The lecture method, while still effective, demonstrated a gender-based difference in performance, which could be attributed to various social, psychological, or behavioral factors influencing learning.

Research question three explored the mean achievement scores and standard deviations for male and female students taught using the gamification-based approach. Both genders showed notable improvements, with male students starting with a higher pre-test score but experiencing a larger improvement in their post-test scores. Female students, while starting with a lower pre-test score, also showed significant improvement. The findings suggest that the gamification method provided an opportunity for all students to actively engage with the content, regardless of gender, and produced more varied results compared to the lecture method. The variability in scores suggests that gamification allows for greater individual engagement with the content, as different students respond differently to game-based elements like rewards and challenges. This finding supports previous studies that suggest that gamification can enhance learning outcomes across genders, as it offers a more interactive and motivating platform that may engage students in different ways (Oke *et al*, 2023). Research indicates that gamification can bridge gender gaps in learning, providing a more equal opportunity for both male and female students to succeed (Mellado *et al*, 2024). In contrast to traditional methods, which often show gender-based differences in performance, gamification seems to level the playing field and allow for a more equitable learning environment.

CONCLUSION

This study demonstrated that the gamification-based approach significantly enhanced students' understanding of complex biology concepts compared to traditional lecture methods. The findings revealed that students in the experimental group, who engaged in the interactive, game-like learning environment, exhibited greater improvement in their achievement scores. This approach fostered higher engagement and motivation, which contributed to a deeper conceptual grasp of topics such as energy transformation, thermodynamics, and ecological phenomena. The study highlights the potential of gamification in improving biology education, suggesting that it can be an effective pedagogical tool for making complex subjects more accessible and engaging for students.

Based on the findings, it is recommended that educators incorporate gamification techniques into their teaching strategies to enhance student engagement and understanding of challenging concepts. Schools should invest in training teachers on effective gamified learning methods, ensuring the integration of game elements that promote active participation. Further research should explore the long-term effects of gamification on student retention and academic performance across different subjects and educational levels.

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