Effect of Gamification on the Academic Achievement of Senior Secondary School Students' in Biology in Cross River State, Nigeria

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Abstract

This study investigated the effect of gamification on the academic achievement of secondary school students in Cross River State, Nigeria. The research was guided by two objectives, two research questions, and two null hypotheses. It adopted a quasi-experimental design involving pre-test and post-test with non-equivalent control groups. The target population comprised all Senior Secondary II Biology students, from which a sample of 112 students were drawn using four intact SSII classes in the Calabar education zone. Data were gathered through the Biology Achievement Test, which was validated and confirmed to be reliable. Mean and standard deviation were utilized to answer the research questions, while Analysis of Covariance was applied to test the hypotheses. The findings showed a statistically significant difference in the mean achievement scores of students taught using gamification compared to those taught using conventional teaching method. Conversely, no significant difference was found in the achievement scores of students from urban and rural schools across both instructional strategies. Based on these findings, the study concluded that gamification is more effective than the conventional lecture approach in improving students' academic achievement. It is recommended that teachers incorporate gamified instructional strategies to enhance students' learning outcomes in Biology.

Keywords: *Gamification, Academic Achievement, Location, Biology education, Genetic Drift, Secondary school students, Urban and Rural Schools.*

Introduction

The integration of gamification into biology education has emerged as a transformative approach to enhance student engagement and academic achievement, especially in complex topics like genetic drift. Gamification entails the use of game-like features such as scoring systems, achievement badges and ranking boards within educational activities to stimulate student motivation and foster active involvement in learning.

Genetic drift, a fundamental concept in evolutionary biology, refers to random changes in allele frequencies within a population that can cause significant genetic shifts over time. Although genetic drift is a vital concept, students often find it challenging to understand because it is abstract and involves elements of probability.

Research suggests that gamified instructional materials can improve students' intrinsic motivation and understanding of genetic concepts. For example, Funa, Gabay and Ricafort (2021) showed that gamified platforms enhanced engagement and comprehension among STEM students in the Philippines. Similarly, Sadiku (2024) demonstrated in Niger State, Nigeria, that senior secondary school students taught biology through the GimKit gamification software achieved higher test scores and better knowledge retention than those taught by traditional lectures.

These findings highlight the potential of gamification to make abstract concepts like genetic drift more interactive and relatable, thereby bridging the gap between theory and practical understanding. This approach not only improves academic performance but also fosters a more engaging learning environment.

In Nigerian secondary schools, where traditional teaching methods still dominate, integrating gamification offers a promising way to improve learning outcomes in challenging topics. However, contextual factors such as school location may influence the effectiveness of gamified learning. Urban schools often have better resources, more qualified teachers, and greater access to technology than rural schools, which may affect student performance. For instance, studies in Akwa Ibom State revealed that urban students generally outperform their rural peers academically.

Therefore, this study aims to investigate the effects of gamification on students' academic achievement in genetic drift, with a specific focus on how school location moderates these effects. Understanding this relationship will help tailor innovative teaching strategies to diverse educational contexts and improve biology education across different school settings.

Empirical studies have demonstrated that gamification enhances students' academic achievement in biology. Kayode et al. (2025) investigated how game-based learning platforms affect the engagement levels and knowledge retention of senior secondary school students studying Biology in Kwara State, Nigeria. Employing a quasi-experimental research design, the study involved two groups: an experimental group that received instruction through classroom-based gamified strategies and a control group that was taught using conventional lecture methods. Data were collected using a highly dependable Biology Achievement Test (BAT) and a Student Engagement Questionnaire (SEQ). The results revealed that gamification significantly improved both student engagement and knowledge retention, offering a potential solution to the persistent issues of low student involvement and poor academic performance in the region.

In a similar vein, Udeani and Akhigbe (2020) explored the implementation of a specially designed Biology Concept Game delivered via mobile phones, applied across four instructional approaches: individualized (I), individualized with competition (IC), collaborative (Col), and collaborative with competition (Col-C). This design-based experimental study involved 242 senior secondary school students selected from five intact classes in schools located within Lagos Island Local Government Area of Lagos State, Nigeria. Data collected were analyzed using both descriptive statistics and inferential methods, specifically Analysis of Covariance (ANCOVA) and Multivariate Analysis of Covariance (MANCOVA). The study's findings indicated that integrating game features such as leaderboards, points, badges and game challenges significantly enhanced students' engagement, academic achievement and attitudes toward learning Biology.

The positive effects of gamification were statistically significant across combinations of dependent variables, including engagement and achievement, engagement and attitude, and the trio of engagement, achievement and attitude. Additionally, the research highlighted the important moderating roles of competition and collaboration in shaping learning outcomes within the gamified biology classroom. However, the results showed no significant main effect of gender or gender interaction with gamification on students' learning outcomes.

Li and Jianxing (2025) conducted an empirical study to assess the effect of gamified learning monitoring systems on students' learning behaviours and academic achievement. The study evaluated 22 gamified learning systems implemented over the past decade, focusing on their effect on student engagement and performance. The results revealed a significant positive correlation, indicating that gamified systems moderately enhance both student engagement and academic outcomes. Uko, Akanwa and Ndirika (2024) carried out an empirical study to examine the effect of gamification on the academic achievement of senior secondary school Biology students in the topic of population ecology within Akwa Ibom State, Nigeria. The research employed a quasi-experimental design and was directed by two null hypotheses. The study population comprised 8,364 Senior Secondary Two (SS2) Biology students, from which a sample of 138 students was selected. Data were collected using a Biology Achievement Test, which had a reliability coefficient of 0.82 ascertained through Kuder Richardson Formula 21. The data were analyzed using mean scores and Analysis of Covariance. The findings showed that students who were taught using gamified instructional strategies performed significantly better in academic achievement than those who received conventional lecture based instruction. Furthermore, the results indicated that gender did not have a significant effect on students' academic performance.

Kalogiannakis, Papadakis and Zourmpakis (2021) conducted a systematic review to evaluate empirical evidence on the application of gamification in science education. Motivated by the growing use of technology in science curricula to counter declining student motivation and promote scientific thinking, the study aimed to synthesize current research findings. The authors systematically reviewed 24 empirical studies published between 2012 and 2020, sourced from various electronic databases and academic search engines such as Google Scholar. Their analysis highlighted recent developments and trends in gamification within science education, while also identifying existing gaps, challenges and limitations in the literature.

Additionally, the review examined inconsistencies in previous research findings and offered a conceptual framework to guide future studies, addressing content areas, educational levels, theoretical foundations, outcomes, research methodologies, game design elements and assessment instruments. Subhash and Cudney (2018) conducted a systematic literature review to empirically examine the integration of gamification and game based learning systems in higher education. Recognizing the growing influence of technology in classrooms, the study addressed the pedagogical shift from traditional lectures to digitally enriched, interactive learning environments. These environments incorporate game elements such as goal orientation, competition, teamwork, and communication that have been shown to enhance learner motivation and engagement. The authors systematically searched academic databases to identify and select peer reviewed studies focused on gamification in educational settings. The review analyzed various frameworks and implementations of game based learning systems, aiming to categorize their effectiveness and application in higher education contexts.

Empirical findings from the reviewed studies highlighted that gamified systems significantly contribute to improved student engagement, motivation, and academic performance. The review offers valuable insights and practical implications for higher education institutions seeking to adopt gamification strategies as a means to enhance teaching and learning outcomes. Furthermore, Zeng, Sun, Looi and Fan (2024) carried out a meta-analysis in China to investigate the overall effects of gamification on students' academic performance. Their study synthesized data from 22 experimental investigations conducted between 2008 and 2023, all of which compared gamified instructional environments with traditional, non-gamified ones. Applying a random effects model, the results demonstrated a moderately positive impact of gamification on academic performance, with a Hedges's g of 0.782 and a statistically significant p-value below 0.05.

Agbaje and Awodun (2014) conducted an empirical study to investigate the effect of school location on the academic achievement of science students in the Senior Secondary School Certificate Examination. The main aim was to assess whether students' academic performance in Biology, Chemistry and Physics is affected by their geographical location. The study adopted an ex post facto research design of the survey type. The population consisted of Senior Secondary Three

(SS III) science students in public secondary schools within Ekiti West Local Government Area of Ekiti State, Nigeria. A total of 120 science students participated in the study, with 20 students randomly selected from each of the six public secondary schools included. Data were sourced from computerized result sheets issued by the West African Examinations Council (WAEC) for the May/June West African Senior Secondary School Certificate Examinations conducted between 2010 and 2013.

The average scores in Biology, Chemistry and Physics for each student served as the measure of academic achievement in science. Three research hypotheses were developed and examined using t-test statistical analysis at a 0.05 level of significance. The findings indicated that there was no statistically significant difference in the average achievement scores of male and female students in rural schools. Additionally, the findings indicated no significant difference in academic performance based on gender among students in rural areas. Likewise, Aniekan (n.d.) carried out an empirical investigation to assess the impact of school location and teaching methods on students' academic achievement and retention in Biology in Ikot Ekpene Local Government Area.

The study targeted a population of 656 Senior Secondary Two (SS2) Biology students enrolled in the seven senior secondary schools in the area during the 2013/2014 academic session. A quasi-experimental research design was utilized, specifically employing the pretest-posttest nonequivalent control group approach. Data were collected using pretest and retention test instruments, and were analyzed using Analysis of Covariance (ANCOVA), with the pretest scores serving as covariates. All hypotheses were evaluated using a significance level of 0.05. The findings revealed that school location did not significantly affect students' academic performance in the topic of carbohydrate nutrients when taught using Demonstration, Computer Assisted Instruction, and Guided Inquiry teaching approaches. However, school location was found to have a significant effect on students' retention of the same concept under these instructional methods.

Edet, Akpan, and Nkoyo (2023) conducted an empirical study to investigate the effect of instructional materials and school location on students' academic performance in Biology in Akwa Ibom State, Nigeria. The research was directed by three research questions and three null hypotheses. A quasi-experimental design was employed, specifically the pretest-posttest nonequivalent control group design. The study involved two experimental groups and one control group across six coeducational public secondary schools in Uruan Local Government Area. A total of 264 Senior Secondary One (SS1) Biology students from intact classes were selected and randomly assigned to experimental and control groups based on school location. Experimental group one was taught using a Microscope, experimental group two received instruction with a Microbes Instructional Kit, and the control group was taught without any instructional materials.

Data were collected using a researcher developed instrument titled Microorganisms Unit Test (MUT), which had a reliability coefficient of 0.87. Analysis of data was carried out using mean, standard deviation, and Analysis of Covariance (ANCOVA) at a significance level of 0.05. The findings revealed that students taught using the Microscope and the Microbes Instructional Kit performed significantly better in Biology than those who received instruction without instructional materials. Furthermore, school location was found to have a significant effect on students' academic performance. However, the combined effect of school location and instructional material was not statistically significant.

Theoretical framework

This study is grounded in two key theoretical perspectives: Self-Determination Theory (SDT) by Deci and Ryan (1985) and Constructivist Learning Theory by Piaget (1936). Together, these frameworks offer valuable insights into how gamified instructional strategies can influence student motivation, engagement, and academic achievement, particularly in the context of teaching complex biological concepts such as genetic drift.

Self-determination theory by Deci et al., (1985)

Self-Determination Theory highlights that human motivation is fueled by the satisfaction of three fundamental psychological needs: autonomy, competence, and relatedness. When learners experience these needs as being met, they are more likely to become intrinsically motivated, which enhances their engagement, performance, and sense of personal growth.

In the classroom, gamification supports these needs in the following ways:

1. Autonomy is encouraged by allowing students to make choices about their learning activities and progress.
2. Competence is supported by presenting appropriately challenging tasks and providing immediate feedback to help learners improve.
3. Relatedness is fostered through collaborative game-based tasks and peer interaction.

By aligning instructional strategies with these motivational drivers, educators can create an engaging and supportive learning environment that enhances students' interest and achievement in biology topics such as genetic drift.

Constructivist learning theory by Jean Piaget (1936)

Constructivist Learning Theory holds that knowledge is actively constructed by learners as they engage with new experiences. Learning becomes meaningful when students are involved in hands-on, reflective activities that connect to their existing knowledge.

Gamification applies constructivist principles by promoting active involvement, where students take part in decision-making and problem-solving within game contexts, providing experiential learning through simulations and role-playing that make abstract biological concepts like genetic drift more tangible and relatable as well as encourage reflection, as instant feedback in games allows learners to assess and refine their understanding.

Incorporating constructivist methods in gamified lessons helps deepen students' comprehension and fosters higher-order thinking skills. The combination of Self-Determination Theory and Constructivist Learning Theory offers a solid theoretical base for understanding how gamification can impact learning. While SDT explains how motivational factors influence student behavior, the constructivist perspective highlights how knowledge is formed through active participation. When used together, these theories justify the use of gamified strategies in teaching genetic drift, as they can boost student engagement, foster deeper understanding, and improve academic outcomes.

Objective of the Study

This study determined the effect of gamification on biology students' academic achievement in genetic drift in Cross River State, Nigeria. Specifically, the study is designed to determine:

1. the effects of gamification on students' academic achievement in genetic drift.
2. the effects of school location on students' academic achievement in genetic drift.

Research questions

1. What is the average achievement score of Biology students taught using gamification and those taught using conventional lecture method?
2. What is the average achievement score of urban and rural students in genetic drift when taught with gamification and conventional lecture method?

Research hypotheses

The study was guided by the following hypotheses:

HO_1: There is no significant difference between the mean achievement scores of students on the topic of genetic drift when taught using gamification and when taught without it.

HO_2: There is no significant difference in the average achievement scores of urban and rural students on the topic of genetic drift when taught using gamification and when taught without it.

Research methods

The research utilized a quasi-experimental design featuring a pretest-posttest control group. This design enabled the researcher to assess the effect of gamified instruction on students' academic achievement in the topic of genetic drift, while examining the moderating role of school location (urban vs. rural). Two groups, experimental and control, were selected from both urban and rural school environments.

The target population consisted of all Senior Secondary School II (SS II) Biology students in public secondary schools in Calabar Municipality Local Government Area, Cross River State, Nigeria. This class level was selected because the topic of genetic drift is included in their curriculum.

A multi-stage sampling method was employed to select the sample. In the first stage, schools were stratified into urban and rural categories based on the classification provided by the State Ministry of Education. In the second stage, two schools were randomly selected from each stratum, with one assigned to the experimental group and the other to the control group. In the third stage, intact SS II classes from each selected school were used to avoid disrupting the existing school structure.

The final sample included 112 students, comprising 68 from urban schools and 44 from rural schools. The experimental group comprised 62 students (38 urban and 24 rural), while the control group comprised 50 students (30 urban and 20 rural). This uneven distribution reflected the natural class sizes of the selected schools and provided a more realistic representation of student populations in the study area.

The instrument used for data collection was a researcher-developed Biology Achievement Test on Genetic Drift (BAT-GD), comprising 30 multiple-choice items. The test items were based on key concepts related to genetic drift. The BAT-GD was validated by experts in biology education and educational measurement. A pilot test was conducted with a similar group of students outside the study sample and the reliability of the instrument was established using the Kuder-Richardson Formula 20 (KR-20). The reliability coefficient obtained was 0.74, indicating that the instrument was reliable.

Students in the experimental group learned about genetic drift through gamified teaching methods. These methods involved engaging activities, including a hands-on simulation game where beads and dice were used to demonstrate changes in allele frequencies. The lessons were designed to promote engagement and understanding through competition and feedback. In contrast, the control group received instruction through conventional lecture-based methods without any gamified elements.

The treatment lasted for three weeks, with three biology periods per week. Each period lasted 40 minutes. A pretest was administered to both experimental and control groups before the intervention to assess their prior knowledge of genetic drift. After the three-week instructional period, a posttest was administered using the same BAT-GD to measure academic achievement following the treatment.

Descriptive statistics, including mean and standard deviation, were used to summarize the pretest and posttest scores of the students. Analysis of Covariance (ANCOVA) was used to determine the effect of gamified instruction on students' academic achievement in genetic drift while controlling for pretest scores. All hypotheses were examined using a significance level of 0.05.

Prior to data collection, ethical approval was obtained from the Research Ethics Committee of the University of Calabar. Additionally, official permission was sought and obtained from the Cross River State Ministry of Education and the principals of the selected schools. Permission was obtained from both the students and their teachers through informed consent. Participants were assured of the confidentiality of their responses and informed that their participation was voluntary and that they could withdraw from the study at any point without penalty.

Results and discussions

Research question 1: What is the average achievement score of Biology students taught using gamification and those taught using conventional lecture method?

Table 1 presents the pre-test and post-test mean scores of students, comparing the gamification and conventional lecture methods. In the treatment group (gamification), which consisted of 62 students, the pre-test mean score was 24.40 with a standard deviation of 6.71. After the intervention, the post-test mean score increased significantly to 28.37, with a standard deviation of 5.04. This resulted in a notable mean gain of 3.97, demonstrating a considerable improvement in students' academic performance following the use of gamification.

Table 1: Mean and standard deviation of pre-test and post-test means scores of students' taught using gamification and those taught using conventional lecture method?

Teaching Methods	N	Pre – test		Post – test		Mean difference between the pre-and post-test of treatment and Control groups
		Mean	SD	Mean	SD	
Gamification	62	24.40	6.715	28.37	5.045	3.47
Lecture	50	24.36	4.624	24.90	5.258	

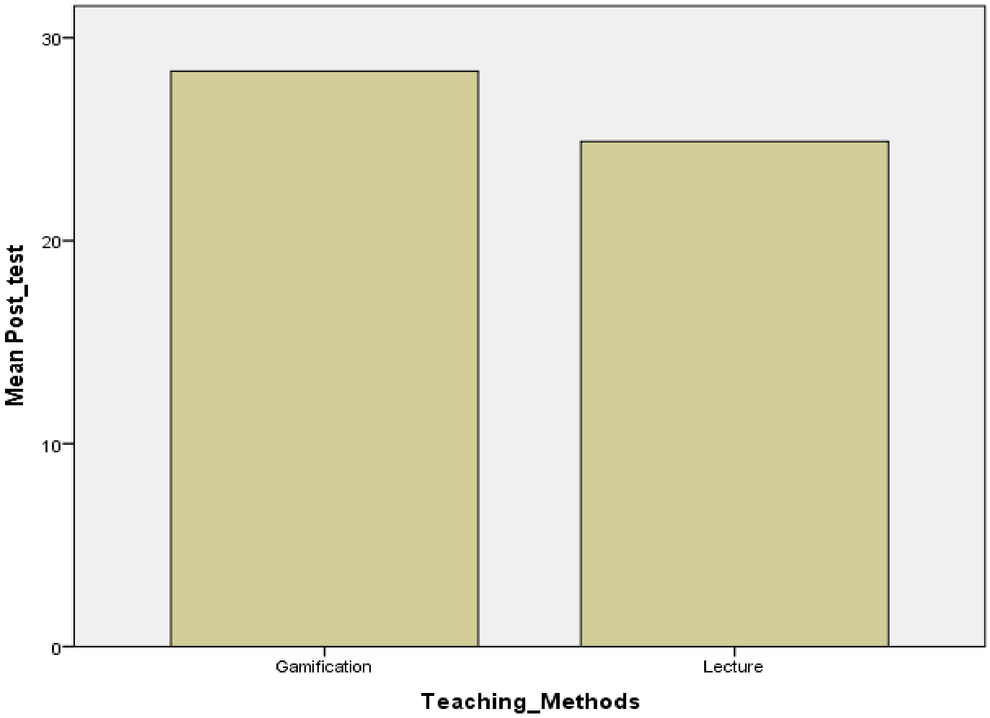

Figure 1. Comparison of mean post-test scores between students taught with gamification (n=62) and conventional lectures (n=50).

Conversely, the control group, taught using the conventional lecture method, comprised 50 students. Their pre-test mean score was 24.36, with a lower standard deviation of 4.62. After the instructional period, the post-test mean score rose to 24.90, with a standard deviation of 5.25. The mean gain of 0.54 between the pre-test and post-test scores of the control group indicates a moderate improvement in academic performance through conventional teaching. The average difference between the treatment group and the control group is 3.47.

As visualized in Figure 1, the post-test scores of the treatment group markedly exceeded the control group, with tighter score distribution (smaller SD). These findings suggest that the gamification strategy was more effective in enhancing students' academic achievement compared to the convention lecture method. The greater mean difference observed in favour of the gamification group highlights its potential to improve students' understanding and application of Biology concepts more effectively than conventional teaching approaches.

Ho_1: There is no significant difference between the average achievement scores of students taught using gamification and those taught using conventional lecture methods.

Table 2: ANCOVA of the difference between the mean achievement scores of students' taught using gamification and those taught with conventional lecture method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	356.766[a]	2	178.383	6.743	.002	.110
Intercept	3693.260	1	3693.260	139.602	.000	.562
Pre_test	23.305	1	23.305	.881	.350	.008
Teaching_Methods	332.806	1	332.806	12.580	.001	.103
Error	2883.663	109	26.456			
Total	83812.000	112				
Corrected Total	3240.429	111				

a. R Squared = .110 (Adjusted R Squared = .094)

Table 2 presents a summary of the ANCOVA analysis conducted to determine whether a significant difference exists between the mean scores of students taught using the gamification strategy and those taught through the conventional lecture method. The results indicate a significant difference in mean achievement scores between the two groups, F (1, 111) = 12.580 580, p = 0.001 < 0.05, with a moderate effect magnitude, as demonstrated by a partial Eta squared value of 0.1.

Research question 2: What is the average achievement scores of urban and rural students on the topic of genetic drift when taught using gamification and when taught without it?

Table 3: Mean and standard deviation of the post-test means achievement scores of urban and rural students' taught using gamification and conventional lecture methods.

Location	N	Post – test		Mean Difference between the post test of Gamification and Control groups based on school location.
		Mean	SD	
Urban	68	26.49	5.276	0.85
Rural	44	27.34	5.615	

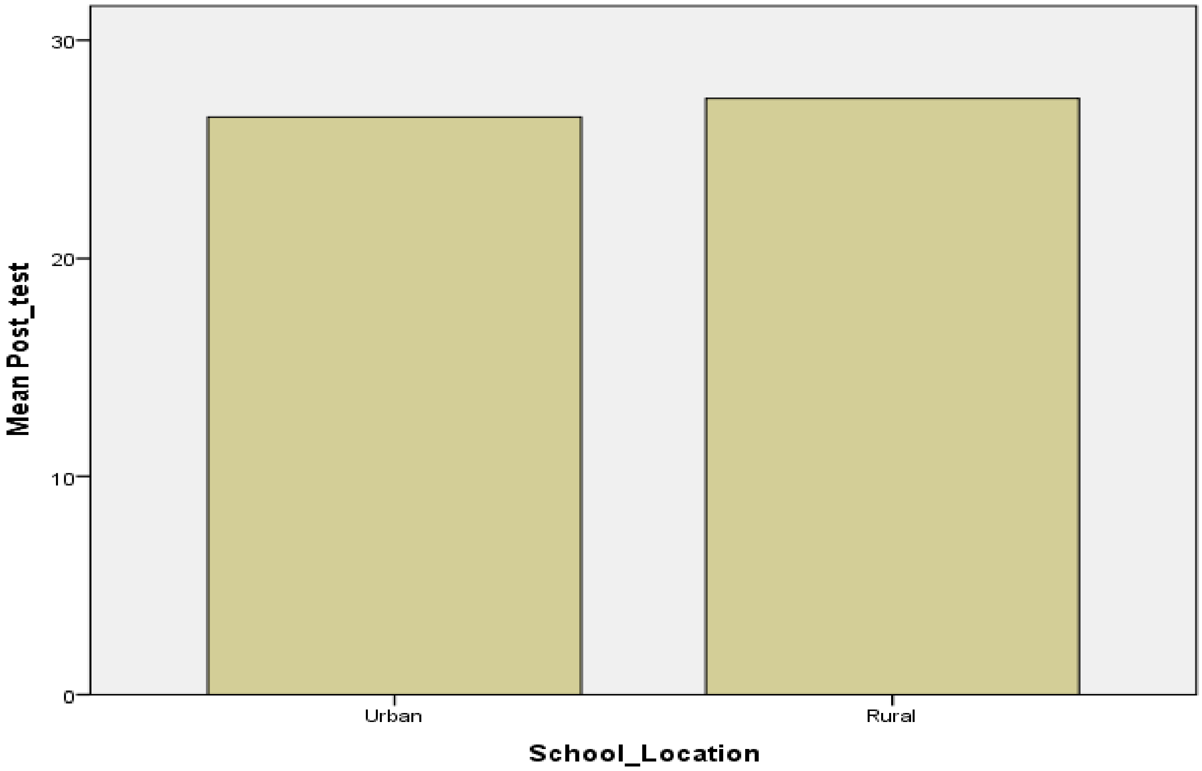

Figure 2. *Post-test scores by school location*

Table 3 presents the post-test mean achievement scores of urban and rural students, comparing the effectiveness of the gamification and lecture methods. The urban location consisted of 68 students, who achieved a post-test mean achievement score of 26.49 with a standard deviation of 5.27. In contrast, the rural location included 44 students, who obtained a slightly higher post-test mean achievement score of 27.34, with a standard deviation of 5.61. This resulted in a minor mean difference of 0.85 between the two locations in favour of the rural students.

As visualized in Figure 2, although small mean differences exist (0.85 between the urban and the rural students in favour of the rural students), ANCOVA analysis in table 4 revealed no statistically significant students' achievement gap across urban and rural schools' $F(1,111) = 0.612$, $p = 0.436 > 0.05$.

Ho_2: There is no significant difference in the average achievement scores of urban and rural students on the topic of genetic drift when taught using gamification and when taught without it.

Table 4 presents a summary of the ANCOVA analysis conducted to determine whether a significant difference exists between the mean achievement scores of urban and rural students taught genetic drift using the gamification and lecture methods. The results indicate no significant difference in mean scores between urban and rural students across both instructional methods, $F(1, 111) = 0.612$, $p = 0.436 > 0.05$. Additionally, the very small effect size, as shown by the partial Eta squared value of 0.006, suggests that location has little to no effect on students' academic achievement in relation to the teaching methods used.

Table 4: ANCOVA of the difference between the mean achievement scores of urban and rural students in genetic drift taught with and without gamification.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	41.932[a]	2	20.966	.714	.492	.013
Intercept	3759.346	1	3759.346	128.113	.000	.540
Pre_test	22.375	1	22.375	.762	.384	.007
School_Location	17.972	1	17.972	.612	.436	.006
Error	3198.497	109	29.344			
Total	83812.000	112				
Corrected Total	3240.429	111				

a. R Squared = .013 (Adjusted R Squared = -.005)

Discussion of findings of the study

The findings from this study indicated a statistically significant enhancement in the academic achievement of students who were taught the concept of genetic drift through gamification compared to those instructed using conventional lecture methods. This outcome aligns with the studies of Sadiku (2024), Kayode et al. (2025), Udeani and Akhigbe (2020) and Uko, Akanwa and Ndirika (2024), all of whom independently reported that learners exposed to gamified instructional strategies attained significantly higher academic achievement scores than those taught through conventional approaches. Conversely, the result showed that school location did not significantly affect students' academic achievement. This finding is consistent with those of Agbaje and Awodun (2014) and Aniekan (n d), who also found no statistically significant difference in achievement scores between students in rural and urban settings.

However, this contrasts with the study conducted by Akpan and Nkoyo (2023), which revealed a significant influence of school location on academic performance. The discrepancy observed in their study may be attributed to differences in research focus and geographical context. While Akpan and Nkoyo examined the influence of instructional materials and school location on Biology performance in Akwa Ibom State, the present study explored the effect of gamification on students' academic achievement in genetic drift in Cross River State.

To provide a theoretical basis for these findings, they can be interpreted through established educational frameworks and contemporary research on gamified learning. According to Self Determination Theory (Deci & Ryan, 1985), intrinsic motivation is strengthened when three psychological needs namely, autonomy, competence, and relatedness are satisfied. Gamified instruction, particularly through simulations of biological concepts such as genetic drift, fosters autonomy by enabling students to make decisions and regulate their learning pace. This aligns with the need for self-direction, which enhances learner engagement. The competence aspect is supported by real time feedback mechanisms, such as scoring, progression levels and visual indicators of mastery, which reinforce a sense of achievement.

Additionally, when gamified tools incorporate peer interaction or collaborative tasks, they satisfy the need for relatedness by promoting connection and shared learning experiences. These components work synergistically to enhance students' intrinsic motivation, resulting in deeper cognitive engagement and higher academic achievement. The elevated achievement of the experimental group in this study can thus be attributed to the motivational influence fostered by gamification, as explained by Self Determination Theory.

Moreover, the findings are supported by Constructivist Learning Theory (Piaget, 1936), which posits that knowledge is actively constructed through interaction with the learning environment. Genetic drift, being an abstract and complex topic, becomes more accessible through simulation based gamification, as it allows students to manipulate variables and observe genetic changes in a dynamic context.

This hands on experience is consistent with Piaget's principle of cognitive conflict and active exploration. Students are engaged in hypothesis formation, experimentation, and conceptual revision based on the feedback received through gameplay, reflecting the processes of assimilation and accommodation. These interactive learning experiences correct misconceptions and foster meaningful, long lasting understanding rather than surface level memorization. Gamified learning environments also support learners within their Zone of Proximal Development by presenting challenges that are slightly beyond their current abilities but achievable with guidance and feedback. This scaffolding approach encourages continuous conceptual development and confidence in learning science content.

These conclusions are further substantiated by international research. For example, Li and Jianxing (2025) found that gamified learning monitoring systems in Asian contexts significantly enhanced student engagement and academic outcomes. Similarly, a systematic review by Kalogiannakis, Papadakis, and Zourmpakis (2021) highlighted that the integration of gamification into science education boosts learner motivation and conceptual understanding when appropriately designed and implemented. In a related study conducted in the Philippines, Funa, Gabay and Ricafort (2021) demonstrated that gamified learning platforms significantly improved engagement and understanding of genetic concepts among STEM students.

Collectively, these studies reinforce the conclusion that technology enhanced instructional strategies, especially those incorporating gamification, can effectively support student learning in science education by encouraging active participation and making content more personally relevant and engaging.

Pedagogical implications

The results of this study underscore the urgent need for the Cross River State Ministry of Education to promote the adoption of innovative pedagogical strategies such as gamified simulations to enhance biology learning outcomes in public secondary schools in the State. The following specific actions are recommended:

1. The Ministry should organize regular teacher training, capacity building and professional development workshops for biology teachers in Cross River State. These programs should focus on equipping teachers with the skills to design and implement gamified instructional strategies that foster learner autonomy, provide timely feedback, and support collaborative learning in the biology classroom.
2. The Ministry should initiate curriculum review and policy Implementation of the current biology curriculum to incorporate gamification as an instructional approach. Educational policy makers within the State should align curriculum objectives with game based learning principles, ensuring that the use of game elements supports the development of conceptual understanding, particularly in abstract topics like genetics.
3. The Ministry of Education should ensure equitable provision of digital tools, teaching aids and ICT infrastructure across urban and rural schools to facilitate the successful integration of gamified learning environments. This will bridge the digital divide and provide all students regardless of school location with access to enriched learning experiences.

Conclusion

This study demonstrates that gamified instruction can significantly enhance the academic achievement of students in genetic drift, while school location does not significantly affect outcomes. Through the lenses of Self-Determination Theory and Constructivist Learning Theory, it is evident that gamification supports motivation, engagement, and conceptual understanding. These findings underscore the potential of gamification as a transformative tool in biology education and call for its broader implementation in science classrooms. Future research should continue to refine gamification strategies and explore their applicability across diverse educational settings and content areas.

Despite the promising results, this study has limitations.

1. It was conducted within a limited geographic area and focused solely on genetic drift. Future studies should explore the impact of gamification on other challenging biology topics such as meiosis, ecosystem dynamics, or molecular biology.
2. Additionally, longitudinal studies are needed to assess the long-term effects of gamified instruction on academic performance and retention.
3. Research should also consider the varying effects of gamification based on students' learning styles, technological access and teacher proficiency in using educational technology.

Recommendations for policy directions

Drawing from the study’s findings, the following recommendations are suggested:

1. In light of the significant improvement in students' academic achievement through gamification, it is recommended that biology teachers in secondary schools adopt gamified instructional strategies, particularly for teaching abstract genetic concepts such as genetic drift. Educational authorities should also provide training and instructional support to help teachers effectively integrate gamification into their lesson delivery.
2. Given that school location did not have a statistically significant effect on students’ academic performance, it is recommended that the Cross River State Ministry of Education ensure equitable distribution of gamified learning resources and training opportunities

across both urban and rural schools. This will help maintain uniform standards of biology education regardless of geographical location.

References

Agbaje, R. O. and Awodun, A. O. (2014). Impact of School Location on Academic Achievement of Science Students in Senior Secondary School Certificate Examination. *International Journal of Scientific and Research Publications*, *4*(9), 1-4.

Aniekan, U-O. (n.d.). School location and teaching methods as determinants of students' performance and retention in Biology in Ikot Ekpene Local Government Area. Retrieved 10 April, 2025 from *https://globalacademicstar.com/download/article/school-location-and-teaching-methods-as-determinants-of-students-performance-and-retention-in-biology-in-ikot-ekpene-local-government-area.pdf*

Deci, E. L. & Ryan, R. M. (1985). Intrinsic Motivation and Self-Determination in Human Behavior. New York: Plenum Press.

Edet, C. G., Akpan, I. F. & Nkoyo, A. T. (2023). Effect of Instructional Materials and School Location on Students' Academic Performance in Biology in Akwa Ibom State, Nigeria. *Inter-Disciplinary Journal of Science Education (IJ-SED)*, *5*(1), 63-72.

Funa, A. A., Gabay, R. A. E. & Ricafort, J. D. (2021). Gamification in Genetics: Effects of Gamified Instructional Materials on the Stem Students' Intrinsic Motivation. *Jurnal Pendidikan IPA Indonesia*, *10*(4), 462-473. Doi: 10.15294/jpii.v10i4.32143

Kalogiannakis, M., Papadakis, S. & Zourmpakis, A.-I. (2021). Gamification in Science Education. A Systematic Review of the Literature. *Educ. Sci.*, *11*(22), 1-36. https://doi.org/10.3390/educsci11010022

Kayode, O. O., Gbigbadua, A. D. & Sulyman, R. (2025). Effect of Game-Based Learning Platforms on Senior Secondary Student Engagement and Knowledge Retention in Biology in Kwara State, Nigeria. *Rima International Journal of Education (RIJE)*, *4*(1), 117-128.

Li. D. & Jianxing, W. (2025). The effect of gamified learning monitoring systems on students' learning behavior and achievement: an empirical study. *Entertainment Computing*, 52, 100907.

Piaget, J. (1936). La naissance de l'intelligence chez l'enfant *"The Origin of Intelligence in the Child"*, Neuchâtel: Delachaux et Niestlé.

Sadiku, A. (2024). Effects of GimKit gamification software on the achievement and retention of senior secondary school Biology students in Minna Metropolis, Niger State. Bichi Journal of Technology Education, 7(2), 59–69.

Subhash, S. & Cudney, E. A. (2018). Gamified learning in higher education: A systematic review of the literature. *Computers in human behavior*, *87*(192-206. https://doi.org/10.1016/j.chb.2018.05.028

Udeani, U. N. & Akhigbe, J. N. (2020). Gamification as an Instructional Approach under Collaborative and Competitive Modes: An Analysis of Students' Learning Outcomes in

Biology. *International Journal of Innovative Technology Integration in Education (IJITIE*), *4*(1), 46-60.

Uko, M. J., Akanwa, U. N. & Ndirika, M. C. (2024). Effect of Gamification on Academic Achievement in Population Ecology among Senior Secondary School Biology Students in Akwa Ibom State. *International Journal of Research Publication and Reviews*, *5*(11), 7242-7246.

West African Examinations Council. (2015–2024). *Senior Secondary Certificate Examination (SSCE) Biology past questions.* Lagos, Nigeria: Author.

Zeng, J., Sun, D., Looi, C-K & Fan, A. C. W. (2024). Exploring the impact of gamification on students' academic performance: A comprehensive meta-analysis of studies from the year 2008 to 2023. *British Journal of Educational Technology*, *55*, 2478–2502. https://doi.org/10.1111/bjet.13471