Effect of Simulation-Based Learning Strategy on Academic Achievement in Genetics among Pre-Service Biology Teachers in Ogun Central Senatorial District, Ogun State

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ABSTRACT

A fundamental aspect of Biology which poses significant challenges to pre-service Biology teachers due to the way it is being taught is Genetics. This study examined the Effect of Simulation-based Learning Strategy on Academic Achievement in Genetics among Pre-service Biology teachers in Ogun Central Senatorial District, Ogun State, Nigeria. Using a quasi-experimental design, 62 pre-service Biology teachers from two intact classes in two tertiary institutions participated in the study and were assigned to: simulation-based learning strategy (SBLS) and traditional teaching strategy (TTS). Guided by one hypothesis, the study lasted a period of eight weeks, using Genetics Achievement Test (GAT) (KR-20 = 0.79) for data collection, which was analyzed through Analysis of Covariance (ANCOVA). The result showed no significant effect in academic achievement between the two groups ($F_{(1, 59)} = 0.809$, $p > 0.05$), with Partial Eta Squared = 0.014. This indicates that only 1.4% of the variance in posttest scores was attributable to the teaching strategy employed. The study concluded that there is no significant effect of simulation-based learning strategy on academic achievement of Pre-Service Biology Teachers in Genetics in Ogun Central Senatorial District, Ogun State. This implies that, simulation could be a useful instructional tool, while its isolated use may not sufficiently enhance academic outcomes without complementary teaching approaches or adequate facilitator training. It is therefore recommended that Simulation-based learning Strategy be combined with other teaching strategies to improve learning and achievement in Genetics for pre-service Biology teachers in Ogun State.

Keywords: Simulation-based learning, Genetics, Academic achievement, Pre-service Biology teachers, teaching strategy

INTRODUCTION

Academic achievement reflects the learning outcomes of students and is typically measured through assessments that capture both knowledge acquisition and skill development. It plays a crucial role in the sciences, where a deep conceptual understanding is essential for academic progression and professional competence. Numerous studies have shown that students perform better academically when exposed to innovative and student-centered instructional strategies, particularly those that promote active and experiential learning (Cayubit, 2022; Sakineh & Ali, 2020; Gisoi, Njagi & Mungiria, 2023). Furthermore, academic achievement has been identified as a strong predictor of future success, especially in Science, Technology, Engineering, and Mathematics (STEM) disciplines (Idris, Govindasamy, Nachiappan & Bacotang, 2023).

In the Nigerian context, particularly in Ogun State, Biology is a foundational subject in the training of future educators at institutions of education. These pre-service teachers play a significant role in promoting scientific literacy at the secondary school level. Biology covers a wide range of sub-disciplines, including Genetics, a core area that is vital for understanding the structure and function of living organisms. Success in this area is critical not only for the personal academic growth of pre-service teachers but also for the effective teaching of complex scientific concepts in secondary schools.

The academic performance of pre-service Biology teachers in Genetics is influenced by several factors such as teaching quality, resource availability, and students' motivation. High achievement in this area is essential for developing teachers who possess both a strong command of biological content and the pedagogical skills required to communicate complex ideas effectively. Unfortunately, Genetics is often perceived as a difficult topic due to its abstract nature and the cognitive demands it places on learners. Topics such as DNA replication, gene expression, and genetic inheritance require a high level of conceptual clarity, which many students struggle to attain (Gericke & Mc Ewen, 2023; Machová & Ehler, 2023; Novakovsky, Dexter, Libbrecht, Wasserman & Mostafavi, 2023).

Recognizing these challenges, educators have introduced a range of instructional strategies designed to enhance understanding and improve academic achievement. These include inquiry-based learning, project-based learning, and cooperative learning. Each of these methods encourages active student involvement, promotes critical thinking, and enhances knowledge retention (Wale & Bishaw, 2020; Firdausih & Aslan, 2024; Ferguson-Patrick, 2020). However, the outcomes of these strategies have not always been consistent across different student populations. As a result, attention has shifted toward newer methods, such as audio-visual aids and simulation-based strategies, particularly in subjects like Genetics where visualization is key to understanding (Ali, Ibrahim, Falode & Daudu, 2024; Arshad, Ishak & Zaharudin, 2024).

Simulation-based instruction is a method that uses interactive models to replicate real-life biological processes in a virtual environment. This approach allows students to visualize abstract genetic phenomena and engage with the content in a more hands-on and meaningful way. It promotes active learning and enhances students' problem-solving and critical thinking abilities (Nkok, 2021; Chernikova, Heitzmann, Stadler, Holzberger, Seidel & Fischer, 2020; G'ofurova & Kimsanova, 2024). Simulations can replicate complex biological systems such as genetic inheritance patterns, mutations, and cellular mechanisms, offering students an immersive experience that traditional lectures may not provide (Akhigbe & Ogufere, 2020; Low & Ellefson, 2024; Irmer, Traub & Neuhaus, 2024).

Despite its potential, simulation-based learning faces certain implementation challenges. These include the cost of acquiring appropriate technology, the need for teacher training, and the risk of over-reliance on virtual environments at the expense of traditional laboratory practices. Addressing these challenges requires institutional support, access to affordable tools, and a balanced integration of virtual and physical learning experiences (Chernikova, Heitzmann, Stadler, Holzberger, Seidel & Fischer, 2020).

Given the importance of Genetics in the professional preparation of Biology educators, and the growing interest in simulation-based instructional methods, this study aims to explore the effect of simulation-based strategy on academic achievement in genetics among pre-service Biology teachers in Ogun Central Senatorial District of Ogun State, Nigeria. By filling the existing research gap, the study seeks to determine how simulation-based strategies can enhance the understanding of Genetic concepts and improve academic outcomes among pre-service teachers, thereby contributing to more effective science education in Nigeria.

Statement of the Problem

Genetics, a fundamental aspect of Biology, poses significant learning challenges for pre-service Biology teachers in Institutions of education within Ogun Central Senatorial District, Ogun State, Nigeria. The abstract nature of concepts such as gene expression, DNA replication, and inheritance often leads to poor academic performance and inadequate comprehension, which ultimately affects the quality of Biology instruction in secondary schools. Despite the integration of various learner-centered strategies, traditional methods still dominate classrooms, offering limited opportunities for deep engagement and conceptual understanding. Simulation-based instructional strategies, which allow students to interact with dynamic models of biological processes, have shown potential to enhance academic achievement by promoting active learning and visualization. However, there remains a gap in empirical evidence regarding their effectiveness in the Nigerian teacher education context. This study, therefore, seeks to examine the effect of simulation-based strategies on the academic achievement of pre-service Biology teachers in Genetics, aiming to provide practical insights for improving science education in the region.

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Purpose of the Study

This study investigated the Effect of Simulation-based Strategy on Academic Achievement in Genetics among Pre-service Biology Teachers in Ogun Central Senatorial District of Ogun State, Nigeria.

Hypothesis

The following null hypothesis was tested at 0.05 level of significance:

$H_0$1: There will be no significant effect of simulation-based learning strategy on academic achievement in Genetics among pre-service Biology teachers in Ogun Central Senatorial District of Ogun State, Nigeria.

METHODOLOGY

This study adopted a quasi-experimental design employing a pre-test and post-test structure to examine the effectiveness of simulation-based learning strategies on academic achievement in Genetics among pre-service Biology teachers. The research focused on two groups, each exposed to a different instructional strategy. The target population comprised 62 pre-service Biology teachers (31 males and 31 females) from two tertiary institutions in Ogun Central Senatorial District, Nigeria. These students were selected through a total enumeration technique, which involved the inclusion of all students from intact Biology education classes in the participating institutions. Participants were distributed into one experimental group and one control group. One of the institutions was placed in Group A (Experimental Group), consisting of 30 students (15 males and 15 females), was exposed to the Simulation-based Learning Strategy (SBLS), while the second institution formed Group B (Control Group) included 32 students (16 males and 16 females) who received instruction through the Traditional Teaching Strategy (TTS). Instructional content on Genetics was delivered over an eight-week period by trained lecturers who adhered strictly to the assigned strategies. The Genetics Achievement Test (GAT), developed by the researcher and validated by experts in science education for content, face, and construct validity, served as the main instrument for data collection. A pilot study conducted on 20 students from a University of Education with the Senatorial District in Ogun State where the study was conducted. These set of students were part of the population but were not involved in the main study, yielded a reliability coefficient of 0.79 using Kuder-Richardson Formula 20 (KR-20), confirming the instrument's internal consistency. To evaluate the effectiveness of the instructional strategies on students' academic achievement, data collected were analyzed using Analysis of Covariance (ANCOVA) at the 0.05 level of significance to determine any significant effects of the strategy on academic achievement across the instructional groups, with the pre-test scores used as covariates.

RESULT

Hypothesis (H_0): There will be no significant effect of simulation-based learning strategy on academic achievement in Genetics among pre-service Biology teachers in Ogun Central Senatorial District of Ogun State, Nigeria.

Table 1: Tests of Between-Subjects Effects of Simulation-based Learning Strategy on Academic Achievement in Genetics among Pre-Service Biology Teachers in Ogun Central Senatorial District of Ogun State, Nigeria

Dependent Variable: POSTTEST						
Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	4389.190[a]	2	2194.595	3192.976	0.000	0.991
Intercept	6.008	1	6.008	8.741	0.004	0.129
PRETEST	4045.634	1	4045.634	5886.103	0.000	0.990
STRATEGY	0.556	1	0.556	0.809	0.372	0.014
Error	40.552	59	0.687			
Total	18260.000	62				
Corrected Total	4429.742	61				
a. R Squared = 0.991 (Adjusted R Squared = 0.991)						

Source: Researchers' Fieldwork, 2025

Table 1 presents the result of ANCOVA on the effect of simulation-based learning strategy on academic achievement in Genetics among pre-service Biology teachers in Ogun Central Senatorial District of Ogun State, Nigeria. From the table 1, the F–statistics [$F_{(1, 59)}$] = 0.809 and the probability (significant) value = 0.372. This indicated that the null hypothesis (H_0) that simulation-based learning strategy has no significant effect on academic achievement in Genetics among pre-service Biology teachers in Ogun Central Senatorial District of Ogun State, Nigeria, should be accepted. Hence, there was no significant effect of simulation-based learning strategy on academic achievement in Genetics among pre-service Biology teachers in Ogun Central Senatorial District of Ogun State, Nigeria [$F_{(1, 59)}$ = 0.809, $p > 0.05$]. The Partial Eta Squared value indicates the effect size of simulation-based learning strategy and traditional teaching strategy. This value was 0.014, which was small when compared with Cohen's guidelines (0.2 – small effect, 0.5 – moderate effect, 0.8 – large effect). This suggested that about 1.4% of the variance in the posttest score of the pre-service Biology teachers' academic achievement in Genetics in Ogun Central Senatorial District of Ogun State, Nigeria was explained by simulation-based learning strategy.

Table 2: Parameter Estimates of Simulation-Based Learning Strategy on Academic Achievement in Genetics among Pre-Service Biology Teachers in Ogun Central Senatorial District of Ogun State, Nigeria

Dependent Variable: POSTTEST							
Parameter	**B**	**Std. Error**	**T**	**Sig.**	**95% Confidence Interval**		**Partial Eta Squared**
					Lower Bound	**Upper Bound**	
Intercept	0.537	0.215	2.493	0.015	0.106	0.968	0.095
PRETEST	1.293	0.017	76.721	0.000	1.259	1.326	0.990
[STRATEGY=Simulation-based Learning]	0.197	0.219	0.899	0.372	-0.241	0.634	0.014
[STRATEGY=Traditional Teaching]	0.000[a]	0.000	0.000	0.000	0.000	0.000	0.000
a. This parameter is set to zero because it is redundant.							

Source: Researchers' Fieldwork, 2025

Table 2 shows the coefficients of the parameters included in the analysis. One could observe that simulation-based learning strategy had positive but insignificant effect on the pre-service Biology teachers' academic achievement in Genetics in Ogun Central Senatorial District of Ogun State, Nigeria since the coefficient of the simulation-based learning strategy was 1.197 and was not statistically significant at 1%, 5% and 10% levels. The outcome implied that simulation-based learning strategy inconsequentially contribute to the academic achievement of the pre-service Biology teachers in Genetics in Ogun Central Senatorial District of Ogun State, Nigeria.

Table 3: Pairwise Comparisons of Simulation-Based Learning Strategy on Academic Achievement in Genetics among Pre-Service Biology Teachers in Ogun Central Senatorial District of Ogun State, Nigeria

Dependent Variable: POSTTEST						
(I) Strategy	**(J) Strategy**	**Mean Difference (I-J)**	**Std. Error**	**Sig.[a]**	**95% Confidence Interval for Difference[a]**	
					Lower Bound	**Upper Bound**
Simulation-Based Learning	Traditional Teaching	0.197	0.219	0.372	-0.241	0.634
Traditional Teaching	Simulation-Based Learning	-0.197	0.219	0.372	-0.634	0.241
Based on estimated marginal means						
a. Adjustment for multiple comparisons: Bonferroni.						

Source: Researchers' Fieldwork, 2025

Table 3 presents the results of the post hoc tests (i.e., pairwise comparisons) that were carried out to see which groups differ. The tests showed that there was no significant difference between simulation-based learning strategy and traditional teaching strategy ($p > 0.05$).

Table 4: Estimates of Simulation-Based Learning Strategy on Academic Achievement in Genetics among Pre-Service Biology Teachers in Ogun Central Senatorial District of Ogun State, Nigeria

Dependent Variable: POSTTEST				
Strategy	**Mean**	**Std. Error**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
Simulation-based Learning	15.037[a]	0.154	14.728	15.346
Traditional Teaching	14.840[a]	0.149	14.542	15.139
a. Covariates appearing in the model are evaluated at the following values: PRETEST = 11.0645.				

Source: Researchers' Fieldwork, 2025

Table 4 shows the results of the estimated marginal mean, which gives the adjusted means (controlling for the covariate 'pretest score') for each strategy group. This simply means that the effect of 'pretest score' has been statistically removed. The outcomes of the estimated marginal means showed that higher academic performance was recorded for the pre-service Biology teachers in Genetics in Ogun Central Senatorial District of Ogun State, Nigeria with simulation-based learning strategy (mean = 15.037 unit) on average after adjusting for pretest score, compared to the traditional teaching strategy (mean = 14.840).

DISCUSSION OF FINDINGS

The study revealed that the simulation-based learning strategy did not produce a statistically significant effect on the academic achievement of pre-service Biology teachers in Genetics within Ogun Central Senatorial District. This outcome diverges from earlier research, such as the study by Akhigbe and Ogufere (2020), which reported that computer simulations notably enhanced students' academic performance and positively influenced their attitudes toward Biology. That research suggested simulations were particularly beneficial in engaging students and promoting a deeper understanding of complex biological concepts.

Additionally, previous findings have shown that computer simulations significantly improved the academic outcomes of students with lower academic abilities, enabling them to achieve greater progress than their peers in higher ability groups. This contrasts with the present study's outcome, where no significant improvement was observed across the board Chernikova, Heitzmann, Stadler, Holzberger, Seidel and Fischer (2020).

Another study by Nkok (2021), which investigated the effect of computer simulations on students' performance and retention in the topic of sexual reproduction in plants in Niger State, also reported that students exposed to simulation-based instruction outperformed those who were taught through traditional methods. The ANCOVA results in Nkok's study indicated that the group taught with simulations achieved significantly higher scores in both academic achievement and content retention.

In contrast, the current study, although applying a similar simulation-based strategy, yielded different results. This discrepancy may be attributed to differences in contextual factors such as sample characteristics, institutional environment, or even the instructional delivery of the simulation-based content. While prior studies such as Chernikova, Heitzmann, Stadler, Holzberger, Seidel and Fischer (2020) demonstrated the effectiveness of simulations in enhancing learning outcomes, the present research suggests that such outcomes are not guaranteed and may vary depending on specific educational contexts and implementation fidelity.

CONCLUSION

Based on the findings of this study, it can be concluded that the simulation-based learning strategy did not have a statistically significant effect on the academic achievement of pre-service Biology teachers in Genetics within Ogun Central Senatorial District of Ogun State. The minimal effect size suggests that only a small

portion of the variation in students' academic performance could be attributed to the use of this strategy. Despite its potential, the simulation-based approach did not demonstrate a clear advantage over traditional teaching methods in this context, highlighting the need for further investigation into factors that may influence its effectiveness in tertiary science education.

RECOMMENDATION

Based on the findings from this study, it is recommended that Simulation-based learning should be integrated with other instructional methods to enhance academic achievement in Genetics. Additionally, teacher training on effective use of simulation tools is essential to maximize their impact.

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