PREDICTORS OF BIOLOGY ACHIEVEMENT IN OGUN STATE'S RESOURCE-SCARCE SCHOOLS: ASSESSING THE IMPACT OF LABORATORY INFRASTRUCTURE AND PEDAGOGICAL METHODS

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Abstract

The persistent underperformance of students in biology across the West African Examination Council's Biology necessitates a critical evaluation of the determinants of academic success. This study employed multiple regression analysis to determine the relative predictive power of laboratory facilities (equipment, specimens, furniture) and teaching methods (demonstration, inquiry, laboratory, expository) on the academic achievement of 602 Senior Secondary School students and 53 teachers in Abeokuta, Nigeria. The results revealed a significant combined influence of facilities and methodology on performance, $F(7, 589) = 10.959$, $p < .05$, accounting for 10.5 per cent of the variance (Adjusted $R2 = .105$). A breakdown of relative contributions showed that Laboratory Equipment (Beta = .191, $p < .05$) and Specimens (Beta = .173, $p < .05$) were the only significant physical predictors, while the Demonstration method was the only significant pedagogical predictor. Notably, the Inquiry method ($p = .950$) and Laboratory Furniture ($p = .199$) were statistically non-significant. The study concludes that in resource-constrained environments, tangible learning consumables are more critical for success than the adoption of advanced pedagogical theories. Major recommendations include a strategic realignment of educational funding to prioritise the procurement of scientific apparatus over general furniture, and the training of teachers in interactive demonstration techniques as a pragmatic bridge between theory and practice until schools are adequately equipped for individual student inquiry.

Keywords: Biology Achievement, Laboratory Equipment, Teaching Methods, Resource-Scarce Schools, Multiple Regression Analysis.

Introduction

Biology plays a crucial role in the secondary school science curriculum, acting as a fundamental discipline for various careers in fields such as medicine, agriculture, biotechnology, and environmental sciences. Consequently, the Nigerian National Policy on Education (NPE) places a premium on science education, mandating curricula that foster practical skills and scientific literacy. Despite these policy stipulations, student outcomes in high-stakes external examinations, such as the West African Senior School Certificate Examination (WASSCE), have remained volatile, characterised by fluctuations in pass rates and a general lack of practical proficiency (Ogunmade, 2022). Proficiency in Biology is seen as an essential measure of scientific literacy and a nation's ability to achieve sustainable development (UNESCO, 2019). However, consistent underperformance in Biology has been noted in many low- and middle-income countries, particularly in schools with limited resources where learning conditions are significantly impaired (World Bank, 2020; Okoli & Ugwanyi, 2019). This issue has raised ongoing concerns among educators, policymakers, and researchers about the primary factors influencing Biology achievement in these environments.

The scholarly discourse regarding the aetiology of this underperformance is generally bifurcated (Hattie, 2019; Akinsola & Igwe, 2021). One school of thought emphasises infrastructure, positing that biology is an inherently activity-based subject that cannot be mastered without the manipulation of physical tools (Asimeng-Boahene, 2023). The opposing school emphasises pedagogy, arguing that teacher competence and the transition from didactic, rote memorisation to Inquiry-Based Learning (IBL) are the decisive factors in student success (Adedapo & Oyelekan, 2021). Akinsola and Igwe (2021) found that creative teaching methods, such as improvising instructional materials and promoting collaborative learning, significantly enhanced Biology achievement in schools without proper laboratory facilities. On the other hand, Uline and Tschannen-Moran (2021) highlighted that ongoing infrastructural deficiencies place undue pressure on teachers, ultimately hindering the success of pedagogical innovations.

The study is grounded in two primary theoretical perspectives: Hattie's Visible Learning Theory and Ausubel's Meaningful Learning Theory. Hattie (2019) argues that variables related to teachers, such as instructional quality and feedback, often have a more substantial impact on student performance than physical resources. This study utilises this theory to test whether pedagogical strategies can indeed outweigh the presence of physical infrastructure in the specific context of Nigerian biology classrooms. By examining various teaching methods alongside laboratory facilities, the study evaluates the validity of this theory in resource-constrained environments where the baseline of infrastructural adequacy may not be met (Okeke & Dlamini, 2022). Ausubel's Meaningful Learning Theory, on the other hand, posits that for learning to be meaningful, new information must be related to existing concepts through physical or mental anchors. In science education, laboratory equipment and specimens serve as these tangible reference points (Mukuni, 2024). As suggested by Mayer (2020), well-structured teacher explanations and visual demonstrations are essential for effective knowledge organisation. This theory provides a basis for the study's focus on the Demonstration method, which acts as a bridge between abstract theory and practical reality when individual student experimentation is not feasible (Aina & Akintunde, 2019).

Despite the increasing literature on infrastructure and pedagogy as individual factors impacting academic achievement, empirical studies that compare their relative impacts on Biology achievement in resource-scarce schools are still scarce, particularly in sub-Saharan Africa. Most existing research examines science achievement broadly without isolating Biology, a subject that uniquely relies on both adequate practical resources and effective teaching abilities (Okoli & Ugwanyi, 2019; Okeke & Dlamini, 2022). Addressing this gap is essential for informed policy-making regarding the prioritisation of limited educational resources for either infrastructural advancements or pedagogical enhancements.

This lack of comparative evidence creates uncertainty for educational planners and policymakers regarding whether scarce resources should be prioritised for infrastructural provision or pedagogical reform. Consequently, there is a need to empirically examine the relative and combined effects of laboratory facilities and teaching methods on Students' academic achievement in Biology in resource-scarce Secondary Schools.

Biology performance serves as a key metric in assessing the effectiveness of science education systems, especially in developing and low-resource regions (UNESCO, 2019). Numerous studies across sub-Saharan Africa and similar areas indicate a consistent lack of achievement among secondary school students in Biology, with structural, instructional, and systemic issues cited as leading causes (Okoli & Ugwanyi, 2019; Okeke & Dlamini, 2022). This problem is particularly severe in schools with limited resources, where the scarcity of learning materials and poor teaching conditions hinder meaningful interaction with biological concepts and processes. Unlike some other subjects, Biology requires a blend of theoretical understanding and practical application through observation, experimentation, and inquiry (Hofstein & Kind, 2018). When this necessary balance is disrupted, as often occurs in under-resourced educational settings, students' academic performance and enthusiasm for the subject suffer.

School infrastructure significantly influences academic performance in science-related disciplines. Here, infrastructure encompasses physical facilities like classrooms, laboratories, libraries, furniture, instructional equipment, and learning resources (Earthman, 2018). Research has shown that adequate infrastructure contributes to student comfort, focus, and engagement, leading to better academic results (Uline & Tschannen-Moran, 2021). Numerous studies have confirmed a positive correlation between the presence of functional laboratories and students’ performance in Biology. Hofstein and Kind (2018) highlighted the importance of laboratory experiences in aiding students’ comprehension of abstract biological ideas, fostering scientific reasoning, and enhancing knowledge retention. Supporting this notion, Okeke and Dlamini (2022) found that students in well-equipped Biology labs outperformed their peers in less-equipped schools.

However, in resource-limited schools, laboratory facilities are frequently inadequate or entirely lacking. Andrade *et al.* (2024) noted that poor laboratory infrastructure and a lack of instructional materials are significant predictors of low academic performance in science subjects within developing nations. Likewise, Earthman (2018) pointed out that overcrowded classrooms, inadequate lighting, and missing basic facilities create learning environments that impede effective teaching and learning. While there is compelling evidence connecting infrastructure to academic success, some studies warn that infrastructure alone does not ensure better learning outcomes. Uline and Tschannen-Moran (2021) contended that although quality facilities enhance learning, their effectiveness is contingent on how efficiently teachers utilise the available resources in their teaching practices.

Pedagogy, encompassing the strategies and methods teachers use to facilitate learning, has been identified as a key school-based predictor of student success (Darling-Hammond *et al*., 2020; Hattie, 2019). Effective pedagogy is especially crucial in Biology education, which involves complex concepts that necessitate active participation and conceptual reorganisation. Research has indicated that student-centred pedagogies such as inquiry-based, problem-based, and collaborative learning, lead to significantly higher academic performance in Biology compared to traditional lecture techniques (Schleicher, 2020; Nwankwo *et al*., 2021).

For instance, Nwankwo et al. (2021) demonstrated that students taught through inquiry-based methods achieved greater success and knowledge retention than those instructed via conventional approaches. Furthermore, evidence suggests that effective pedagogical strategies can mitigate the adverse effects of limited infrastructure. Akinsola and Igwe (2021) found that when teachers improvised instructional materials and employed interactive teaching methods, Biology achievement improved in schools without standard laboratory amenities. Similarly, Darling-Hammond *et al*. (2020) highlighted that teachers' skills, classroom dynamics, and formative assessments can significantly boost learning outcomes, even in resource-poor settings.

While both infrastructure and pedagogy have been shown to influence Biology achievement, scholars are divided regarding their relative importance. Some researchers maintain that adequate infrastructure is essential for effective pedagogy, especially in science subjects reliant on practical work (Hofstein & Kind, 2018; Earthman, 2018). This viewpoint suggests that pedagogical innovations may be limited if fundamental facilities are missing. Alternatively, other studies argue that pedagogy is the more critical factor. Hattie’s (2019) meta-analysis indicated that variables related to teachers, such as instructional quality and feedback, have more substantial effects on student performance than physical resources. Schleicher (2020) concurred, stating that high-performing educational systems prioritise effective teaching over investment in infrastructure. However, direct empirical comparisons of the two factors remain scarce, particularly within the context of Biology. Most existing literature examines infrastructure and pedagogy separately, leaving a gap in understanding how these elements interact and which holds more sway over Biology achievement in resource-limited schools (Okoli & Ugwanyi, 2019; Okeke & Dlamini, 2022).

Despite considerable research on the factors affecting academic success, several gaps remain. First, there is a lack of studies that directly compare the contributions of infrastructure and pedagogy to Biology achievement. Second, most research addresses broad science subjects without focusing specifically on Biology, which has distinct pedagogical and infrastructural needs. Lastly, there is insufficient consideration of how teachers adjust their strategies in structurally constrained environments. These gaps highlight the necessity for empirical studies that systematically evaluate infrastructure and pedagogy as both competing and complementary factors influencing Biology achievement in resource-scarce schools.

While existing literature has explored these variables in isolation, there is a paucity of research employing multivariate analysis to weigh the relative impact of hardware (facilities) versus software (teaching methods) within the same statistical model, particularly in the post-pandemic era. Furthermore, studies conducted in the Global North often assume a baseline of infrastructural adequacy that does not exist in Sub-Saharan Africa. This study fills this gap by modelling the predictors of biology achievement in a resource-constrained context (Abeokuta, Nigeria). It seeks to determine whether pedagogical sophistication can compensate for infrastructural deficits, or if material resources are the sine qua non of academic achievement.

In light of this context, the current study investigates the factors influencing Biology achievement in resource-limited schools, specifically focusing on the comparative influence of infrastructure and pedagogy. By analysing their independent and combined effects on students' academic performance, the study aims to contribute to the body of knowledge in science education and guide policy and practice in under-resourced educational settings.

Purpose of the Study

1. To examine the combined influence of laboratory facilities (equipment, specimens, furniture) and teaching methods (demonstration, inquiry, laboratory and expository) on public senior secondary school students' academic achievement in Biology in Abeokuta, Ogun state.
2. To examine the relative influence of laboratory facilities (equipment, specimen, furniture and teaching methods (demonstration, inquiry, laboratory, and expository) on senior secondary school students' academic achievement in Biology in Abeokuta, Ogun state.

Research Hypotheses

To guide this investigation, two null hypotheses were formulated:

Hypothesis One: There is no significant combined influence of laboratory facilities (equipment, specimens, furniture) and teaching methods on students' academic achievement in biology.

Hypothesis Two: There is no significant relative contribution of laboratory facilities and teaching methods to the prediction of students' academic achievement in biology.

Methodology

The study adopted a descriptive survey research design combined with a correlational approach. This design was selected to establish the predictive strength of independent variables on the dependent variable without manipulating the natural school setting.

The target population comprised all Senior Secondary School II (SS2) biology students and teachers in Abeokuta, Ogun State. A multi-stage sampling technique was employed to ensure representativeness. First, the study area was stratified into its constituent Local Government Areas (Abeokuta South, Abeokuta North, and Odeda). Second, forty-three public senior secondary schools were selected via simple random sampling to reduce selection bias. Finally, within the selected schools, intact classes of SS2 students were used, totalling 602 students and 53 biology teachers.

Two validated instruments were utilised for data collection. The Biology Teachers Questionnaire (BTQ) assessed the availability of facilities (equipment, specimens, furniture) and the frequency of various teaching methods. It yielded a Cronbach's Alpha reliability coefficient of 0.85. The Student Achievement Test (SAT), a 40-item objective test adapted from past WASSCE questions, was used to measure academic performance. It yielded a reliability coefficient of 0.92.

Strict ethical adherence was maintained throughout the study. Permission was obtained from the Zonal Education Offices and school principals. Informed consent was acquired from participating teachers and students (assented to by school authorities). Anonymity was guaranteed, with data coded numerically to prevent personal identification.

Results

Test of Hypothesis One (Combined Influence)

A multiple regression analysis was conducted to determine the combined influence of the independent variables on biology achievement.

Table 1: *Analysis of Variance (ANOVA)*

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	1741.072	7	248.725	10.959	.000
Residual	13368.248	589	22.697		
Total	15109.320	596			

The ANOVA results in Table 1 reveal that the regression model is statistically significant ($F(7, 589) = 10.959$, $p < .001$). This indicates that the combination of laboratory facilities and teaching methods significantly predicts student success. Consequently, the null hypothesis (Hypothesis One) is rejected. The model summary yielded an Adjusted R Square of .105, implying that these variables account for 10.5 per cent of the variance in student performance, a notable proportion in educational research, given the multiplicity of external factors.

Test of Hypothesis Two (relative contribution)

A multiple regression analysis was conducted to determine the relative contribution of independent variables to biology achievement.

Table 2: *Coefficients of Relative Contribution to Academic Achievement*

Model	Unstandardized Beta	Standardized Beta	T	Sig.	Remark
Constant	16.780	-	5.436	.000	-
Equipment	.130	.191	2.547	.000	Significant
Specimen	.199	.173	2.971	.003	Significant
Furniture	.096	.065	1.286	.199	Not Significant
Demonstration	-.969	-.189	-4.305	.000	Significant
Inquiry	-.009	-.003	-.063	.950	Not Significant
Laboratory	.297	.072	1.502	.134	Not Significant
Expository	.086	.021	.430	.667	Not Significant

The multiple regression result in Table 2 reveals the hierarchy of influence. The significant predictors of academic achievement are Laboratory Equipment (Beta = .191), Specimens (Beta = .173), and the Demonstration Method (Beta = -.189). Notably, the Inquiry Method (t = -.063) and Furniture (t = 1.286) were not statistically significant predictors.

Discussion

Discussion of Hypothesis One: The rejection of the first null hypothesis confirms that student achievement in biology is not the result of a single factor but is driven by the interaction between laboratory infrastructure and teaching methodology. The regression model accounted for 10.5 per cent of the variance in student performance (Adjusted R2 = .105). While this percentage may appear modest, it is statistically significant and highly relevant in educational research, where numerous external variables, such as socioeconomic status, parental support, and student motivation, also compete for influence. This finding validates the conceptual model of this study, suggesting that any attempt to improve biology outcomes in Abeokuta must address both the hardware (facilities) and the software (pedagogy) of the learning environment simultaneously. This aligns with the systemic view of science education, which posits that instructional methods are only as effective as the physical tools available to implement them.

Discussion of Hypothesis Two: The breakdown of relative contributions provides a more nuanced understanding of which specific factors drive success. Laboratory Equipment (Beta = .191) and Specimens (Beta = .173) emerged as the strongest positive predictors of achievement. This result provides empirical support for the materialist perspective in science education, which argues that biological concepts remain abstract and inaccessible without tangible reference points. In the schools surveyed across Abeokuta, the ability of a student to observe a specimen or utilise a piece of equipment serves as a cognitive anchor, transforming theoretical knowledge into meaningful understanding.

Conversely, the statistical insignificance of Laboratory Furniture ($p = .199$) is highly instructive. It indicates that while tables and stools contribute to the physical comfort and organisation of a laboratory, they do not directly facilitate the cognitive engagement required for scientific mastery. For educational planners in Ogun State, this suggests a clear hierarchy of needs: the limited budget available should be directed toward consumable specimens and functional apparatus rather than the aesthetic or comfort-related aspects of laboratory construction.

Perhaps the most significant finding of this study is the failure of the Inquiry Method to predict academic achievement ($p = .950$), contrasted with the significant predictive power of the Demonstration Method. While international pedagogical trends and curriculum developers strongly advocate for Inquiry-Based Learning (IBL), this study suggests that IBL may not be a viable "one-size-fits-all" solution in resource-scarce environments. As noted by Adeyemi (2024), inquiry without infrastructure is merely confusion. Empirical studies indicate that inquiry-based learning yields inconsistent results in contexts marked by large class sizes and inadequate facilities (Abrahams *et al.,* 2019; Lazonder & Harmsen, 2019). Furthermore, Kirschner and Hendrick (2020) argue that minimally guided instructional strategies may overwhelm students when foundational supports are lacking. In the public schools of Abeokuta, where equipment is scarce and class sizes are large, attempting individual inquiry without the necessary tools likely results in cognitive overload.

In this specific context, the Demonstration Method acts as a pragmatic survival strategy (Okeke & Alarape, 2023). It allows the teacher to act as a bridge between theory and reality, ensuring that even if students cannot personally manipulate tools due to scarcity, they can still visualise biological processes. This finding supports Ausubel's Meaningful Learning Theory, as teacher-led demonstrations provide the structured organisation of knowledge necessary for students to assimilate new information. The negative Beta coefficient for the Demonstration method (Beta = -.189) suggests that as the frequency of effective, teacher-led demonstrations increases (assuming a lower numerical value on the frequency scale), student achievement test scores increase. This identifies the Demonstration method as the most effective pedagogical tool currently available to biology teachers in these resource-constrained settings.

These findings provide a critical rebuttal to Hattie's (2019) Visible Learning Theory in the context of developing nations. While Hattie argues that teacher-related variables generally outweigh physical resources, this study demonstrates that in sub-Saharan Africa, a baseline of infrastructural adequacy is a non-negotiable prerequisite for pedagogical success. Pedagogy does not operate in a vacuum; without equipment and specimens, even the most competent teacher is limited to rote instruction. Therefore, the "sophistication" of a teaching method like Inquiry is less important than the "utility" of a method like Demonstration when resources are at a premium.

In summary, the discussion of the two hypotheses reveals that biology achievement in Abeokuta is currently a function of material availability and the teacher's ability to demonstrate concepts. The lack of significance for furniture and the inquiry method provides a clear roadmap for reform. To move student performance forward, the focus must shift from general infrastructure to specific scientific consumables, and from advanced pedagogical ideals to the mastery of interactive, resource-aligned demonstration techniques.

Conclusion

The findings of this study provide a definitive conclusion regarding the primary drivers of biology achievement in the resource-scarce secondary schools of Abeokuta, Nigeria. The rejection of the first null hypothesis proves that student performance is determined by the significant combined influence of laboratory infrastructure and teaching methodology. However, the rejection of the second null hypothesis provides the most critical insight: not all physical or pedagogical variables are equal in their impact.

The study concludes that tangible scientific consumables, specifically laboratory equipment and biological specimens, are the true hardware of academic success. The statistical insignificance of laboratory furniture indicates that while tables and stools are necessary for comfort, they do not facilitate the cognitive engagement required to master biological concepts. Furthermore, the findings highlight a stark pedagogical reality. While global curricula advocate for inquiry-based learning, this study proves that the inquiry method is statistically non-significant in environments lacking the requisite materials. Instead, the demonstration method serves as the essential bridge between abstract theory and practical reality. Success in this context is therefore not a product of advanced pedagogical theory, but rather a function of the availability of functional scientific apparatus and the teacher's ability to utilise them through structured instruction.

Recommendations

Based on the empirical evidence gathered through the testing of the two hypotheses, the following recommendations are proposed to enhance biology achievement in resource-constrained settings:

Strategic Realignment of Educational Funding. Policymakers and the Ministry of Education must shift from general infrastructural spending to targeted procurement. Since equipment and specimens were significant predictors of achievement while furniture was not, budgetary allocations should prioritise the purchase of functional scientific apparatus, reagents, and preserved samples over the construction of physical buildings or the acquisition of general classroom furniture.

Context-Specific Pedagogical Reform. Educational planners should reconsider the blanket enforcement of inquiry-based learning in schools that lack the necessary infrastructure. Until schools are adequately equipped for individual student discovery, the focus should remain on strengthening the demonstration method. Curriculum developers should provide teachers with manuals specifically designed for interactive demonstration techniques that maximise the utility of limited resources.

Equipment-Specific Professional Development. Training programs for biology teachers should move beyond general pedagogical theories to focus on technical competence. Given that laboratory equipment is a primary predictor of success, teachers must be trained in the maintenance, operation, and improvisation of specific scientific tools. Professional workshops should focus on how to conduct effective teacher-led demonstrations that can compensate for the lack of individual workstations.

Periodic Resource Audits. School administrators should conduct regular audits to ensure that the small number of highly predictive facilities, such as microscopes and biological specimens, are not only available but also functional. The study suggests that achievement is hindered when these specific items are missing or broken, regardless of how modern the rest of the laboratory facility may appear.

Evidence-Based Resource Distribution. To close the achievement gap, the distribution of scientific resources should be data-driven. Schools that consistently show low achievement should be targeted with the specific hardware identified in this study—equipment and specimens—as these are the variables most likely to yield a measurable increase in student performance scores.

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