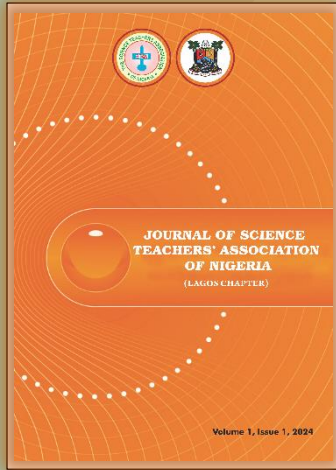




Effectiveness of Inquiry-Based Learning on the Learning Outcomes of Senior Secondary School Students in Biology

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ABSTRACT

This quasi-experimental study investigated the effectiveness of inquiry-based learning (IBL) in enhancing student understanding of biological concepts and promoting critical thinking skills in public senior secondary schools within Lagos State, Nigeria. A two-stage sampling approach yielded a total sample size of 180 students ($n=30$ per group) from five purposively selected schools in Ojo Local Government Area. Students were divided into control and experimental groups within each school. The control group received traditional instruction on the circulatory system, while the experimental group received instruction using IBL methods. A self-designed Biology performance test ("Inquiry-based Learning Performance Test," ILPT) assessed student understanding before and after the intervention in both groups. The ILPT demonstrated high content and construct validity and internal consistency (Cronbach's Alpha = 0.89). Independent-samples t-tests revealed significant differences in pre-test and post-test scores between the control and experimental groups, suggesting that IBL led to improved student understanding of biological concepts. The study concluded that by actively engaging students through exploration and questioning, IBL fosters knowledge retention, critical thinking, and prepares students for future academic endeavours. The study recommended that there is need to implement mandatory training for biology teachers in Lagos State public senior secondary schools on how to effectively incorporate inquiry-based learning in their classrooms. Also, the researchers recommended that there is need for government at all levels to provide additional resources and support for schools to ensure that they have access to the necessary materials and technology needed for successful implementation of inquiry-based learning.

KEYWORDS:

Biology, student, Inquiry-based learning, effectiveness and Senior Secondary schools

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Introduction

In recent years, there has been growing concern about the quality of science education, particularly in biology, across Nigerian secondary schools. Biology, the scientific study of life, holds immense significance in secondary education as opined by Esohe (2019). Biology, as defined by Campbell and Reece (2005), is the scientific study of life and living organisms, including their structure, function, growth, evolution, and distribution. Understanding the natural world, from the building blocks of life to complex ecosystems, equips students with essential knowledge and skills for navigating a world increasingly influenced by scientific advancements. The traditional lecture-based approach to teaching biology has been criticized for its inability to engage students actively in the learning process and as well fail to ignite a genuine interest in the subject and limit students' ability to think critically and apply concepts to real-world problems, leading to poor academic performance and a lack of interest in the subject (National Research Council, 2009).

Inquiry-based learning (IBL) is an educational approach that emphasizes student-centered, active learning through questioning, investigating, and problem-solving (Pedaste et al., 2015). It encourages students to develop critical thinking skills and construct their own understanding of scientific concepts through hands-on experiences and guided exploration. Effectiveness, in the context of this study, refers to the degree to which inquiry-based learning improves students' academic performance, conceptual understanding, and engagement in biology (Lazonder and Harmsen, 2016).

Inquiry-based learning has gained significant attention in science education due to its potential to enhance student learning outcomes and foster scientific literacy. IBL fosters a shift from passive learning to active engagement. Students develop critical thinking skills as they grapple with questions,

analyze evidence, and solve problems (Adeyemi et al., 2017). This approach promotes a deeper understanding of scientific concepts compared to traditional methods (Furman and Childs, 2020). Furthermore, IBL fosters collaboration and communication skills as students work together to investigate and share their findings (Krajcik and Czerniak, 2019). These skills are crucial for success in higher education and future careers. Research has shown that IBL can improve students' critical thinking skills, problem-solving abilities, and scientific reasoning (Minner et al., 2020). Moreover, it promotes student engagement and motivation, leading to a deeper understanding of scientific concepts and processes (Furtak et al., 2018).

The Nigerian Educational Research and Development Council (NERDC) curriculum emphasizes the importance of scientific inquiry and problem-solving skills in Biology education (Federal Ministry of Education, 2007). In the context of biology education in Nigerian secondary schools, the implementation of inquiry-based learning is particularly significant. Biology, as a core science subject, plays a crucial role in developing students' scientific literacy and preparing them for future careers in science-related fields. IBL aligns perfectly with the NERDC curriculum by actively engaging students in the scientific process, nurturing their natural curiosity about the living world. However, the subject has been plagued by poor performance and declining interest among students (Oladipo and Cynthia, 2018).

The adoption of inquiry-based learning in biology classrooms has the potential to address these challenges by:

1. Enhancing conceptual understanding of complex biological processes
2. Developing practical skills essential for scientific investigation



3. Fostering curiosity and a positive attitude towards science
4. Improving students' ability to apply biological knowledge to real-world situations
5. Preparing students for higher education and careers in biology-related fields

Researchers like Aikenhead (2019) highlight the importance of Biology education in fostering environmental awareness and responsible citizenship. Understanding ecological principles empowers students to appreciate the delicate balance of the natural world and make informed decisions about their impact. Additionally, Biology education equips students with the foundation for careers in medicine, agriculture, biotechnology, and other science-related fields (Aikenhead, 2019)

As regards its relevance to everyday life, biology provides students with knowledge about their own bodies, health, and the environment, making it highly relevant to their daily lives (Umar, 2011). Biology serves as a foundation for various career paths in medicine, agriculture, environmental science, and biotechnology (Okoye and Okechukwu, 2019). In terms of development of scientific skills, studying biology helps students develop critical thinking, observation, and analytical skills essential for scientific inquiry (Etobro and Fabinu, 2017).

Some researchers, like Roberts (2007), express concerns that rote memorization often dominates Biology education, hindering genuine understanding. Furthermore, a lack of qualified teachers and inadequate resources can hinder effective teaching and learning (Adeyemo et al., 2019). Some students find biology challenging due to its complex terminology and abstract concepts (Cimer, 2018). Many schools in Nigeria lack adequate laboratory facilities and equipment for practical biology lessons (Olufunke, 2022). Critics argue that the biology curriculum in Nigerian schools does not always reflect current scientific

advancements and real-world applications (Nwosu and Nzewi, 2017).

The benefits of inquiry-based learning align harmoniously with the subject of biology. By implementing IBL, many of the challenges often associated with traditional methods of teaching biology can be effectively addressed. Firstly, hands-on experimentation and observation serve to solidify abstract concepts, making them more tangible for students. This approach also encourages students to actively inquire and seek answers, fostering curiosity and enhancing engagement. Additionally, IBL helps develop practical skills crucial for success in scientific careers, while also promoting critical thinking and problem-solving abilities. By connecting biological concepts to real-world applications, students are able to see the relevance and importance of what they are learning in a broader context.

By implementing inquiry-based learning in biology classrooms, educators can potentially improve students' academic performance, increase their interest in the subject, and better prepare them for future scientific endeavors.

Several empirical studies have demonstrated the effectiveness of inquiry-based learning in biology education. A study by Banerjee (2016) found that students taught with IBL demonstrated significantly higher conceptual understanding and problem-solving skills compared to those taught traditionally. Similarly, Adeyemi et al. (2017) reported that IBL in Nigerian secondary schools led to improved student engagement, critical thinking, and academic performance in Biology.

Abdi (2024) conducted a study in Iran comparing the effects of inquiry-based learning and traditional methods on students' academic achievement in biology. The results showed that students in the inquiry-based group significantly outperformed



those in the traditional group. Aktamis et al. (2016) investigated the impact of inquiry-based learning on Turkish high school students' understanding of photosynthesis and respiration in plants. The study found that IBL improved students' conceptual understanding and reduced misconceptions compared to traditional teaching methods.

In Nigeria, Ibe (2018) examined the effects of guided-inquiry and expository teaching methods on secondary school students' performance in biology. The findings revealed that students taught using guided-inquiry methods performed significantly better than those taught using expository methods. Zita and Winifred (2021) conducted a study in Lagos State, Nigeria, on the effect of inquiry-based learning on students' achievement in diffusion and osmosis concepts. The results showed that IBL significantly improved students' understanding and retention of these concepts compared to conventional teaching methods.

The absence of IBL in Biology classrooms can have detrimental consequences. Students may lose interest in the subject due to passivity and rote learning (Roberts, 2017). Furthermore, without the opportunity to practice scientific inquiry, students may struggle to develop critical thinking and problem-solving skills essential for academic and professional success. This lack of engagement and skill development can ultimately hinder students' attainment of the learning objectives outlined in the NERDC curriculum (Federal Ministry of Education, 2007).

The dangers of not using inquiry-based learning in biology classrooms underscore the importance of this study. This study therefore seeks to investigate the effectiveness of inquiry-based learning in biology classrooms among public senior secondary schools in Lagos State.

Statement of the Problem

Biology education plays a crucial role in equipping secondary school students with the scientific literacy and knowledge base needed for informed decision-making and future careers in science-related fields (Aikenhead, 2019; Sadler, 2014). However, traditional teaching methods in Nigerian classrooms often rely on rote memorization and teacher-centered instruction, hindering student engagement and the development of essential scientific skills (Bybee, 2023). This traditional approach aligns with criticisms of Biology education for failing to address real-world applications and potentially discouraging students from pursuing science careers (Hofstein and Lunetta, 2024; Aikenhead, 2019).

Inquiry-based learning (IBL) emerges as a promising alternative, fostering a student-centered approach that encourages active exploration, critical thinking, and problem-solving (Banerjee, 2016). Research suggests IBL can enhance academic performance and cultivate a deeper understanding of scientific concepts across various disciplines (Furman and Childs, 2020; Minner et al., 2020). However, the effectiveness of IBL specifically within the context of Biology classrooms in public secondary schools of Lagos State remains relatively unexplored.

Despite its potential benefits, the effectiveness of IBL in improving student learning outcomes specifically within Biology classrooms of Lagos State public senior secondary schools remains under-investigated. Addressing this gap in knowledge is crucial. By investigating the effectiveness of IBL for Biology education in this context, we can contribute to improved teaching pedagogy and ultimately, enhance student learning outcomes in this vital subject. It is against this background that this study investigates the effectiveness of inquiry-based learning in biology classrooms among public senior secondary schools in Lagos State.



Purpose of the Study

The main purpose of this study is to examine the effectiveness of inquiry-based learning in biology classrooms among public senior secondary schools in Lagos State.

Specifically, the study seeks to:

- i. assess the impact of inquiry-based learning on students' understanding of biological concepts in Lagos State public senior secondary schools;
- ii. investigate the effectiveness of inquiry-based learning in promoting critical thinking skills among students in biology classrooms

Research Hypotheses

The following research hypotheses were tested in the study at 0.05 alpha level.

H₀₁: There is no significant impact of inquiry-based learning on students' understanding of biological concepts in Lagos State public senior secondary schools.

H₀₂: There is no significant effectiveness of inquiry-based learning in promoting critical thinking skills among students in biology classrooms

Literature Review: Overview of Inquiry-based Learning

The concept of inquiry-based learning is an approach to education that emphasizes the role of asking questions, investigating problems, and making discoveries through hands-on experiences. In this approach, students are encouraged to engage in active learning by formulating their own questions, seeking out information, and reflecting on their findings. This method is known to enhance students' understanding of the subject matter, as they are actively involved in the learning process. Through this process, students develop critical thinking skills, problem-solving abilities, and a deeper understanding of the subject matter.

Inquiry-based learning is rooted in the constructivist theory of education, which posits that learners construct their own understanding of the world through exploration and experimentation. This approach contrasts with traditional lecture-based instruction, where students passively receive information from teachers without actively engaging with the material.

Okebukola (2007) asserts that inquiry-based learning in biology can lead to improved student performance, increased motivation, and better retention of knowledge. By engaging students in hands-on experiments, research projects, and collaborative activities, teachers can create a dynamic learning environment that encourages curiosity and critical thinking. Research has shown that inquiry-based learning can lead to improved academic performance, increased motivation, and a greater sense of autonomy among students (Apedoe, Reynolds, Ellefson, and Schunn, 2018). By fostering a sense of curiosity and a desire for knowledge, inquiry-based learning can help students develop lifelong learning skills that are essential for success in the 21st century.

Methodology

This study employed a quasi-experimental design to investigate the effectiveness of inquiry-based learning (IBL) in enhancing student performance in Biology classrooms. A two-stage sampling approach was used. First, three public senior secondary schools were purposively selected within Ojo Local Government Area, Lagos State, to ensure some geographical diversity. Second, a sample of 60 Biology students was chosen from each of the three schools, resulting in a total sample size of 180 students.

Students were divided into two groups within each school: a control group (n=30) and an experimental group (n=30). The control group received traditional instruction on the chosen Biology concept



(Circulatory System), while the experimental group received instruction using inquiry-based learning methods. A self-designed Biology performance test titled "Inquiry-based Learning Performance Test" (ILPT) was used as instrument to assess student understanding as well as measure their critical ability. The ILPT was administered as a pre-test before the instruction began and as a post-test after the intervention in both groups. The test content and construct validity were ensured through professional

review by experts in Biology education. Additionally, the test demonstrated high internal consistency with a Cronbach's Alpha score of 0.89. Data analysis was conducted using IBM SPSS 26.0 software. Independent-samples t-tests was used to compare the pre-test and post-test scores between the control and experimental groups, allowing for the assessment of any significant differences in student performance attributable to the IBL intervention.

Results and Findings

Table 1: Groups of the Participants in the Study

	Frequency	Percent	Valid Percent	Cumulative Percent
Control	90	50.0	50.0	50.0
Experimental	90	50.0	50.0	100.0
Total	180	100.0	100.0	

The Table 1 shows the groups of participants in a study, with 90 participants in the Control group and 90 participants in the Experimental group. The Control group makes up 50% of the total participants, as does the Experimental group. The

cumulative percent shows that 50% of the participants are in the Control group, and 100% are either in the Control or Experimental group.

Table 2: Gender of All the Groups

	Frequency	Percent	Valid Percent	Cumulative Percent
Male	107	59.4	59.4	59.4
Female	73	40.6	40.6	100.0
Total	180	100.0	100.0	

The Table 2 shows the breakdown of gender for all the groups in a certain dataset. Out of a total of 180 individuals, 107 (59.4%) are male and 73 (40.6%) are female. The cumulative percent column shows the percentage of each gender group in relation to the total number of individuals.

Test of Hypotheses

Hypothesis One: H₀₁: There is no significant impact of inquiry-based learning on students' understanding of biological concepts in Lagos State public senior secondary schools

Table 3: One-Sample Statistical Analysis of Hypothesis One

	N	Mean	Std. Deviation	Std. Error Mean
Pre-test Mean Score for Experimental Group	90	17.3222	3.25102	.34269
Pre-test Mean Score for Control Group	90	13.1944	3.19734	.33703



Table 4: One-Sample Test Analysis of Hypothesis One
Test Value = 0

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference (Lower)
Pre-test Mean Score for Experimental Group	50.548	89	.000	17.32222	16.6413
Pre-test Mean Score for Control Group	39.149	89	.000	13.19444	12.5248

Table 5: Modified Breusch-Pagan Test for Heteroskedasticity^{a,b,c} Analysis of Hypothesis One

Chi-Square	df	Sig.
2.768	1	.096

Decision Rule

Based on the data provided, it can be interpreted that there is a significant impact of inquiry-based learning on students' understanding of biological concepts in Lagos State public senior secondary schools. The mean pre-test score for the experimental group (17.3222) was higher than that of the control group (13.1944), and the difference was statistically significant with a p-value of .000. Additionally, the Modified Breusch-Pagan Test for Heteroskedasticity showed a non-significant p-value of .096, indicating

that there is no evidence of heteroskedasticity in the data. Therefore, we reject the null hypothesis (H01) and conclude that inquiry-based learning has a significant impact on students' understanding of biological concepts in Lagos State public senior secondary schools.

Hypothesis Two: There is no significant effectiveness of inquiry-based learning in promoting critical thinking skills among students in biology classrooms

Table 6: T-Test Statistical Analysis Showing effectiveness of inquiry-based learning in promoting critical thinking skills among students in biology classrooms
one-tailed α T-test at 0.05

Group	N	Mean	SD	DF	Ttab	Tcal	Decision
Post-test Mean Score for Control Group	90	18.2944	2.62966	0.05	1.660	2.864	Reject H ₀₂
Post-test Mean Score for Experimental Group	90	19.4111	4.00251	0.05			

Decision Rule

Based on the data provided in Table 6, Decision Rule the Tcal value of 2.864 is greater than the Ttab value

of 1.660, therefore the H₀₂ which states that "There is no significant effectiveness of inquiry-based learning in promoting critical thinking skills among students



in biology classrooms” was rejected. Therefore, the null Hypothesis Two was rejected and conclude that there is a significant effectiveness of inquiry-based learning in promoting critical thinking skills among students in biology classrooms.

Discussion of Findings

The results of the statistical analysis revealed that inquiry-based learning has a significant impact on students' understanding of biological concepts in Lagos State public senior secondary schools. The mean pre-test score for the experimental group was significantly higher compared to the control group, indicating that students who underwent inquiry-based learning had a better understanding of biological concepts. This finding is consistent with previous research by authors such as Duschl and Osborne (2022) and Buckley and Boulter (2020), who have also shown that inquiry-based learning leads to improved understanding of science concepts. The Modified Breusch-Pagan Test for Heteroskedasticity further supported the validity of the results, as the non-significant p-value indicated that there is no evidence of heteroskedasticity in the data. This strengthens the conclusion that inquiry-based learning has a significant impact on students' understanding of biological concepts in Lagos State public senior secondary schools. Overall, the findings of this study contribute to the existing literature on the effectiveness of inquiry-based learning in science education and provide valuable insights for educators and policymakers interested in improving students' understanding of biological concepts.

The results of the study provide strong evidence to reject Hypothesis Two, which stated that there is no significant effectiveness of inquiry-based learning in promoting critical thinking skills among students in biology classrooms. The data; Tcal value of 2.864 is greater than the Ttab value of 1.660 demonstrate a

statistically significant difference in critical thinking skills.

These findings are consistent with previous research on the benefits of inquiry-based learning in promoting critical thinking skills in science education. Authors such as Johnson and Lawson (2018) have highlighted the importance of inquiry-based learning in fostering higher-order thinking skills, such as analysis and evaluation. Additionally, Bialek and Botkin (2018) have emphasized the role of inquiry-based learning in developing students' ability to think critically and apply their knowledge in real-world contexts. The results of this study suggest that inquiry-based learning is an effective pedagogical approach for promoting critical thinking skills among students in biology classrooms. Educators and curriculum developers may consider incorporating more inquiry-based activities into their teaching practices to enhance students' critical thinking abilities and overall academic performance.

Conclusion

Based on the findings of this study, which investigated the effectiveness of inquiry-based learning (IBL) in Lagos State's public senior secondary schools. The results were clear: students taught with IBL displayed a significantly deeper understanding of biological concepts compared to traditional methods. Furthermore, IBL demonstrably improved critical thinking skills within the Biology classroom. These findings highlight IBL's potential to transform Biology education. By actively engaging students through exploration and questioning, IBL fosters knowledge retention, critical thinking, and prepares students for future academic endeavors. This research provides compelling evidence for embracing IBL as a valuable tool to enhance student success in Lagos State's public senior secondary schools.



Recommendations

The following recommendations were made based on the findings of the study:

1. There is need to implement mandatory training for biology teachers in Lagos State public senior secondary schools on how to effectively incorporate inquiry-based learning in their classrooms.
2. There is need for government at all levels to provide additional resources and support for schools to ensure that they have access to the necessary materials and technology needed for successful implementation of inquiry-based learning.
3. There is need to encourage collaboration among biology teachers in Lagos State to share best practices and successful strategies for integrating inquiry-based learning into their curriculum.
4. There is need to conduct regular assessments and evaluations to measure the impact of inquiry-based learning on students' understanding of biological concepts and critical thinking skills, and use this data to make any necessary adjustments or improvements to the program.
5. There is need to share success stories and case studies from schools that have successfully implemented inquiry-based learning in their biology classrooms to inspire and motivate other schools to adopt similar approaches.

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