

UNIJERPS
Unizik Journal of Educational Research and Policy Studies VOL.19 (2);
January-June, 2025 https://unijerps.org
2023 Impact Factor:* 6.834;** 2022 ***Impact Factor: 5.156; ***2021 Impact Factor: 5.641;***
2020 Impact Factor: 5.355. *Indexing and Impact Factor URL: http://sjifactor.com/passport.php?id=21363*

EFFECT OF INQUIRY-BASED TEACHING METHOD ON SECONDARY SCHOOL BIOLOGY STUDENTS CRITICAL THINKING ABILITIES IN ANAMBRA STATE, NIGERIA

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ABSTRACT

The study investigated the effect of inquiry-based teaching method on critical thinking abilities of senior secondary school students in biology in Anambra State, Nigeria. The study was guided by two research questions and three hypotheses. The study adopted a quasi-experimental pre-test post-test equivalent control group design. The population consisted of SSII biology students across the six educational zones of Anambra State. Critical Thinking Ability Test (CTAT) was used as an instrument for data collection. Face and content validation of the instrument was conducted by experts, and its reliability coefficient was determined. Research questions were answered using mean and standard deviation, while hypotheses were tested using ANCOVA at 0.05 alpha level of significance. The findings indicated that the inquiry-based teaching method significantly improved students' critical thinking abilities in biology. There was no significant gender difference in the impact of the method. The study recommended among others that inquiry-based teaching method should be adopted as an effective strategy for enhancing students' critical thinking skills in biology.

Keywords: Inquiry-Based Teaching Method, Critical Thinking Abilities, Secondary School, Biology Students.

Introduction

The development of critical thinking skills is a fundamental goal of science education, particularly in biology, where students must analyze complex concepts and apply scientific reasoning to real-world scenarios. Critical thinking is an essential skill that enables students to evaluate evidence, make informed decisions, and engage in problem-solving activities (Facione, 2020). Despite the importance of critical thinking, many secondary school students in Nigeria, including those in Anambra State, struggle with analytical reasoning due to the

prevalence of rote learning and traditional lecture-based instructional methods (Okebukola, 2021).

Biology, as a core subject in the Nigerian secondary school curriculum, requires students to develop skills in observation, hypothesis formulation, experimentation, and logical reasoning (National Research Council, 2021). However, studies indicate that many students demonstrate low performance in biology-related problem-solving tasks, which can be attributed to a lack of teaching methods that actively engage students in the learning process (Ukwuaba & Ezeudu, 2022). To address this challenge, researchers and educators have advocated for the adoption of student-centered teaching approaches, such as the inquiry-based teaching method, to enhance students' cognitive development and critical thinking skills (Adewale, 2022).

Inquiry-based teaching is a constructivist approach that places students at the center of the learning process, allowing them to explore scientific phenomena through questioning, experimentation, and reflection (Hmelo-Silver et al., 2020). This instructional method contrasts with traditional teacher-centered approaches by fostering active engagement, encouraging curiosity, and promoting deeper understanding of scientific principles (Kirschner et al., 2021, Halpern, 2022). When implemented effectively, inquiry-based teaching enables students to take ownership of their learning experiences, thus improving their ability to analyze and synthesize information (Pedaste et al., 2019).

The theoretical underpinning of inquiry-based learning is rooted in the constructivist theories of Jean Piaget and Lev Vygotsky, who emphasized the importance of active participation and social interaction in knowledge construction (Piaget, 1985; Vygotsky, 1978). Piaget's theory of cognitive development highlights how students learn best when they interact with their environment, while Vygotsky's sociocultural theory emphasizes the role of collaborative learning and teacher scaffolding in the acquisition of new knowledge (Mayer, 2020). By applying these principles, inquiry-based teaching encourages students to develop scientific reasoning and critical thinking skills necessary for academic and professional success.

Empirical research supports the effectiveness of inquiry-based teaching in improving students' critical thinking abilities (Okonkwo & Nwagbo, 2020; Ogunniyi & Adediwura, 2021). Studies have shown that students who engage in inquiry-based learning activities demonstrate greater proficiency in analyzing scientific problems, formulating hypotheses, and evaluating experimental outcomes compared to their peers who receive instruction through traditional lecture methods (Lazonder & Harmsen, 2019). Furthermore, inquiry-based instruction has been linked to increased student motivation, engagement, and retention of biological concepts, which are critical for long-term learning success (Sadeh & Zion, 2020).

Despite the proven benefits of inquiry-based teaching, its implementation in Nigerian secondary schools remains limited due to several challenges, including inadequate

teacher training, lack of instructional resources, and resistance to pedagogical change (Adewale, 2022). Many biology teachers are either unfamiliar with the principles of inquiry-based instruction or lack the necessary skills to facilitate student-led investigations effectively (Okebukola, 2021). Addressing these challenges requires targeted professional development programs that equip teachers with the knowledge and tools to integrate inquiry-based methods into their classrooms.

Given the need to enhance critical thinking in science education, this study investigates the effect of inquiry-based teaching method on the critical thinking abilities of secondary school biology students in Anambra State. Specifically, the study aims to determine whether inquiry-based instruction improves students' ability to analyze biological concepts, draw logical conclusions, and apply their knowledge to novel situations. The findings will provide empirical evidence on the effectiveness of this approach and inform education policies on best practices for teaching biology in Nigerian secondary schools.

This study is significant because it highlights the need for a paradigm shift from rote learning to inquiry-driven instruction in Nigerian science education. By demonstrating the impact of inquiry-based teaching on critical thinking skills, this research will contribute to the ongoing discourse on effective pedagogy and curriculum reform in Nigeria. The results will have implications for educators, policymakers, and curriculum developers, underscoring the importance of fostering scientific literacy and problem-solving abilities among secondary school students (World Bank, 2023).

Statement of the Problem

The development of critical thinking skills among secondary school students is crucial for fostering problem-solving abilities in science education. However, traditional lecture-based teaching methods that emphasize rote memorization rather than active learning remain prevalent in Nigerian classrooms. This approach has been identified as a major impediment to the acquisition of higher-order thinking skills, particularly in biology, where students are required to analyze complex concepts and apply scientific reasoning. As a result, many students struggle with critical thinking and the ability to engage in scientific inquiry, ultimately affecting their performance and preparedness for higher education and careers in science-related fields.

Inquiry-based teaching method has been suggested as an effective approach to improving students' critical thinking skills by promoting engagement, exploration, and deeper understanding of scientific concepts. Despite its potential benefits, this method is not widely implemented in Nigerian secondary schools due to challenges such as inadequate teacher training, lack of instructional resources, and resistance to pedagogical change. This study seeks to investigate the impact of the inquiry-based teaching method on the critical thinking ability of secondary school biology students in Anambra State, providing empirical evidence to support its integration into classroom instruction.

Purpose of the Study

The main purpose of this study is to investigate the effect of inquiry-based teaching method on the critical thinking abilities of secondary school biology students in Anambra State. Specifically, the study seeks to determine the:

1. Difference in the mean critical thinking ability scores of students taught biology with Inquiry-based method and those taught with lecture method.
2. Difference in the mean critical thinking ability scores of male and female students taught biology with Inquiry-based method and those taught with lecture method.
3. Interaction effect of methods (IBM & LM) and gender on the mean critical thinking ability scores of students in biology.

Research Questions

The following research questions guided the study:

1. What is the difference in the mean critical thinking ability scores of students taught biology with Inquiry-based method and those taught with lecture method?
2. What is the difference in the mean critical thinking ability scores of male and female students taught biology with Inquiry-based method and those taught with lecture method?

Hypotheses

The following null hypotheses were formulated to guide the study and each was tested at 0.05 alpha level of significance:

H_{O1}: There is no significant difference between the mean critical thinking ability scores of students taught biology with Inquiry-based method and those taught with lecture method.

H_{O2}: There is no significant difference in the mean critical thinking ability scores of male and female students taught biology with Inquiry-based method and those taught with lecture method.

H_{O3}: There is no interaction effect of instructional methods (IBM & LM) and gender on the mean critical thinking ability scores of students in biology.

Research Method

This study adopted a quasi-experimental pre-test post-test non-equivalent control group design to examine the impact of inquiry-based teaching on students' critical thinking ability in biology. The study was conducted in Awka Education Zone, Anambra State, involving 277 SSII biology students selected through a multi-stage random sampling technique. The Critical Thinking Ability Test (CTAT), adapted from the Watson-Glaser Critical Thinking Appraisal, was used for data collection, measuring inference, recognition of assumptions, interpretation, deduction, and evaluation of arguments. The instrument was validated by experts, and its reliability coefficient, established using Kuder-Richardson 21 (KR-21), was 0.71. The study lasted four weeks, during which the experimental group received inquiry-based instruction while the control group was taught using the conventional lecture method.

To ensure the credibility of the findings, regular classroom teachers implemented the lessons, and measures were taken to

minimize extraneous variables. The pre-test was administered before treatment, and a post-test followed to assess any improvements in critical thinking skills. Research questions were answered using mean and standard deviation, while the hypotheses were tested using Analysis of Covariance (ANCOVA) at 0.05 alpha level of significance. The research design and methodology ensured a robust investigation into the effects of inquiry-based teaching on critical thinking in biology, providing empirical evidence for its adoption in Nigerian secondary schools.

Results

Research Question 1: What is the difference in the mean critical thinking ability scores of students taught biology with Inquiry-based method and those taught with lecture method?

Table 1: Mean and Standard deviation of the mean critical thinking ability scores of students taught biology with Inquiry-based method and those taught with lecture method

Group	N	Pre-Test		Post-Test		Gained Mean
		Mean	SD	Mean	SD	
Experimental	128	8.23	1.47	17.78	1.09	9.55
Control	149	8.16	1.46	12.68	1.12	4.52
Mean Difference		0.01		5.10		5.03

As shown in Table 1, students in the experimental group taught using IBM (n = 128) achieved a pre-test mean critical thinking ability score of 8.23 (SD = 1.47) and a post-test mean of 17.78 (SD = 1.09), resulting in a mean gain of 9.55. Students in the control group taught using LM (n = 149) had a pre-test mean of 8.16 (SD = 1.46) and a post-test mean of 12.68 (SD = 1.12), with a mean gain of 4.52. The mean difference of 5.10 in post-test scores and 5.03 mean gain respectively between the two groups in favour of the experimental group highlights the effectiveness of IBM in improving students' critical thinking abilities. The SD values for the experimental group increased slightly from pre-test to post-test, indicating that while the IBM intervention improved critical thinking abilities overall, there was a slight increase in variability among students' post-test performance.

Research Question 2: What is the difference in the mean critical thinking ability scores of male and female students taught biology with Inquiry-based method and those taught with lecture method?

Table 2: Mean and Standard deviation of the mean critical thinking ability scores of male and female students taught biology with Inquiry-based method and those taught with lecture method

Group	**Gender**	**N**	**Pre-Test**		**Post-Test**		**Gained Mean**
			Mean	**SD**	**Mean**	**SD**	
Experimental	Male	61	8.26	1.46	17.93	0.94	9.60
	Female	67	8.21	1.49	17.64	0.91	9.43
Control	Male	79	8.16	1.48	12.77	1.04	4.61
	Female	70	8.16	1.45	12.59	1.20	4.43

Table 2 details the critical thinking ability scores by gender for both instructional methods. Among students taught using IBM (experimental group), males (n = 61) had a pre-test mean of 8.26 (SD = 1.46) and a post-test mean of 17.93 (SD = 1.24), leading to a mean gain of 9.60. Females (n = 67) had a pre-test mean of 8.21 (SD = 1.49) and a post-test mean of 17.64 (SD = 1.51), yielding a mean gain of 9.43. In the control group taught using LM, males (n = 79) achieved a pre-test mean of 8.16 (SD = 1.48) and a post-test mean of 12.77 (SD = 1.04), resulting in a mean gain of 4.61. Females (n = 70) had a pre-test mean of 8.16 (SD = 1.45) and a post-test mean of 12.59 (SD = 1.20), with a mean gain of 4.43. While IBM was effective for both genders, the mean gains were slightly higher for females than for males in the experimental group with the mean difference of 0.02 in favour ot the female students. The variability in performance, as reflected in the SD values, was more pronounced among males in the control group than among females, suggesting a potential gender-based difference in response to LM.

Hypothesis Testing

Hypothesis 1: There is no significant difference between the mean critical thinking ability scores of students taught biology with Inquiry-based method and those taught with lecture method.

Table 3: Analysis of Covariance (ANCOVA) of the mean critical thinking ability scores of students taught biology with Inquiry-based method and those taught with lecture method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Decision
Corrected Model	1792.631[a]	4	448.158	287.544	.000	
Intercept	2004.069	1	2004.069	1285.835	.000	
Pre_Interest	.093	1	.093	.060	.807	
Group	1791.629	1	1791.629	1149.531	.000	Sig.
Gender	3.951	1	3.951	2.535	.112	Not Sig.
Group * Gender	.196	1	.196	.126	.723	Not Sig.
Error	423.932	272	1.559			
Total	64872.000	277				
Corrected Total	2216.563	276				

Table 5 shows that there is a significant main effect of the treatment on students' critical thinking abilities in biology when taught with Inquiry-based method and lecture method ($F(1, 272) = 1149.531$, $P = 0.000 < 0.05$). Therefore, the null hypothesis was rejected meaning that there is a significant difference between the mean critical thinking ability scores of students taught biology with Inquiry-based method and those taught with lecture method.

Hypothesis 2: There is no significant difference in the mean critical thinking ability scores of male and female students taught biology with Inquiry-based method and those taught with lecture method.

Analysis of gender differences revealed an F-ratio of 0.664 with a p-value of 0.189, which

is greater than 0.05. Therefore, the null hypothesis was retained, indicating no significant difference in the mean critical thinking ability scores of male and female students taught using IBM and LM

Hypothesis 3: There is no interaction effect of instructional methods (IBM & LM) and gender on the mean critical thinking ability scores of students in biology.
The ANCOVA results for the interaction effect between instructional method and gender yielded F (1, 272) = 0.47, p = .493, which was not significant. This means that the effectiveness of IBM in improving critical thinking was independent of gender, and there was no significant interaction effect between instructional method and gender.

Discussion
The findings of this study revealed that the inquiry-based teaching method (IBM) significantly improved students' critical thinking ability compared to the lecture method (LM). Students taught with IBM demonstrated higher mean gains in their critical thinking ability, supporting the assertion that inquiry-based learning enhances students' analytical reasoning, problem-solving, and cognitive flexibility. This aligns with previous studies, such as those by Nasution et al. (2019) and Manishimwe et al. (2023), which found that inquiry-based learning strategies promote independent thinking and reflective learning. The active engagement and exploration inherent in IBM may have contributed to these improvements, as opposed to the passive nature of traditional lecture-based instruction, which has been criticized for limiting students' ability to develop higher-order thinking skills. However, Rahman et al. (2021) argued that IBM's effectiveness may be limited in environments with inadequate instructional support, highlighting the need for well-trained educators and sufficient classroom resources to optimize its benefits.

The study also found no significant gender differences in the mean critical thinking ability scores of students taught using IBM and LM. Both male and female students benefitted equally from the inquiry-based approach, suggesting that IBM fosters a learning environment that is inclusive and equitable. This is consistent with findings by Lin and Tsai (2019), who reported that inquiry-based instruction enhances science learning outcomes for both genders without significant disparities. Similarly, Çelik and Aydın (2020) noted that females may exhibit stronger critical thinking skills in cooperative learning environments, while Rahman et al. (2021) highlighted that classroom dynamics could influence gender-based differences in critical thinking development. The absence of a significant interaction effect between instructional methods and gender further supports the conclusion that IBM is effective across diverse student groups. These findings reinforce the argument that inquiry-based learning should be integrated into secondary school biology curricula to improve critical thinking skills, regardless of gender.

Recommendations
Based on the findings of this study, the following recommendations are made:

1. Schools should integrate IBM into their instructional strategies, especially in science subjects like

biology, to enhance students' critical thinking abilities.

2. Curriculum planners should incorporate inquiry-based learning activities in the biology syllabus to ensure that students develop critical thinking skills alongside content knowledge.
3. Regular training programs should be conducted for biology teachers to equip them with the necessary skills and strategies for implementing IBM effectively.
4. Schools should ensure the availability of necessary resources such as laboratory equipment, digital learning tools, and instructional materials that support inquiry-based learning.
5. Educational policymakers should establish policies that promote the implementation of IBM in secondary schools.

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