EFFECTS OF GUIDED-INQUIRY AND OPEN-INQUIRY METHODS ON BIOLOGY STUDENTS' ACADEMIC ACHIEVEMENTS AND RETENTION IN SENIOR SECONDARY SCHOOLS OF ADAMAWA STATE, NIGERIA

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Abstract
The study investigated the effects of guided-inquiry and open-inquiry methods on Biology students' academic achievements and retention in Senior Secondary Schools of Adamawa State, Nigeria. four Objectives, and four hypotheses were formulated and tested and 0.05 level of significance. The study adopted quasi-experimental design which involved pre-test, post-test, non-equivalent, and control group design. The research population comprised of 11,916 SSII students, offering Biology in public Senior Secondary Schools in Yola Education Zone of Adamawa state. The sample of this study comprised of 217 biology students (126 males and 91 females) from three intact classes which were selected using purposive sampling technique. The instrument for the data collection was Biology Achievement Test (BAT). The BAT was adapted from WASSCE 2020 to 2024, with the coefficient reliability of 0.81, data collected where analyzed using descriptive statistics (mean and standard deviation) and two-way Analysis of Variance (ANOVA) and MANOVA at 0.05 level of significance. The findings of the study showed that: (i) There is significant difference between the mean achievements score of students taught biology using guided-inquiry, open inquiry and those taught with lecture methods (F = 55.033, p = .000). (ii) There is no significant difference between the mean achievements score of students taught biology using guided-inquiry and open inquiry by gender (F = 1.452, p = 0.229). (iii) There is significant difference between the mean retention scores of students when taught biology using guided-inquiry, open inquiry and lecture methods (F = 36.489, p = .000). (iv) There is significant difference between the mean retention scores of students taught biology using guided-inquiry, open-inquiry by gender. (F = 6.046, p = .015. It was recommended that educators and policymakers should promote and support the consistent use of guided and inquiry-based, gender-neutral instructional strategies in Biology, as they enhance academic achievement and content retention equally for all students.

Introduction

Education is the bedrock of any nation's development and is central to all aspects of any nation's economy. It is the total process of human learning by which knowledge is impacted, faculties trained and skills developed (Abolarin, 2019). Education, according to Ugwu (2019) can be regarded as the process of imparting and acquiring general knowledge, as an instrument for effecting human learning, and for transformation and capacity development. Thus, it is a means through which man acquires learning and is

molded to fit into the society. In the National Policy on Education, the Federal Republic of Nigeria (FRN, 2014) had continued to update her educational system to meet up with various educational challenges. Senior secondary education in Nigeria, on its part, aims at equipping students to live effectively in our modern age of science and technology, hence, the inclusion of science education in the secondary school curriculum in Nigeria. The Nigeria secondary school science education curriculum lay emphasizes on the teaching and learning of science subjects through hands-on activity based teaching methods (Adebayo & Yusuf, 2022).

There have been various discussions regarding the teaching and learning of science overtime. This is because there has been increased emphasis on the development of individuals through innovation and development of creative ideas which is entrenched in the National Policy of Education (FRN). The policy state that "the first cardinal aim for effective scientific teaching is to bring about development of scientific inquiry and abilities in students towards creativity" (FRN, 2014:14). Scientific teaching and learning is expected to promote the gaining of knowledge, skills and attitude which will culminate in societal development. The societal development is more paramount in recent times because the characteristic of the 21st century society is the advancement in science and technology (NSF). This advancement is supposed to bring about overall change in the perspective of individuals living in the 21st century society. For Nigeria to achieve this development in the 21st century, there is a need for qualitative science education in educational institutions especially in Senior Secondary Schools and that can be seen in the students' academic achievements (NSF, 2019).

Ali, Toriman and Gasim (2014) observed a significant decline in students' Biology academic achievements in both West Africa Senior School Certificate Examination (WASSCE) and Senior School Certificate Examinations (SSCE) in Nigeria. This decline has been attributed to several factors, including the unavailability of textbooks, poor and inadequate laboratory apparatus, and other essential learning resources, as well as the failure of teachers to adopt appropriate teaching methods (Ali et al., 2014). Thus, while the human elements in education are crucial for promoting engagement and critical thinking, the lack of necessary resources and effective teaching methods may hinder students' academic achievements, particularly in subjects like Biology. Arokoyu and Chimuanye (2017) buttressed the fact that the achievements of students in Biology in Nigeria up until 2017 has been below 45%. This implies that the method of teaching was a significant factor affecting the academic achievements of students in Nigeria. The method employed by the teachers in an attempt to impact knowledge on the students to determine what knowledge students will acquire after the lesson (Kareem, 2019).

The poor achievements of students in Biology in external examinations in Adamawa state has been attributed to ineffective teaching methods (WAEC Chief Examiner's Report, 2022). Although various methods have been introduced to improve student achievement, many have failed to yield significant results due to factors such as inadequate teacher training, lack of instructional resources, and the diverse levels of students' prior knowledge and engagement (Nkechinyere & Arokoyu, 2018). In response to these challenges, it is essential for educators to adopt more innovative and student-centered approaches to enhance teaching and learning outcomes. Among the methods recommended for 21st-century education

are inquiry-based teaching methods, particularly guided inquiry and open inquiry. Guided inquiry involves the teacher providing a structured framework for investigation while allowing students to explore and draw conclusions independently. In contrast, open inquiry empowers students to formulate their own research questions, design experiments, and analyze results with minimal teacher intervention. These approaches promote critical thinking, active participation, and a deeper understanding of biological concepts, making them effective alternatives to traditional teaching methods (Nkechinyere & Arokoyu, 2018).

Inquiry teaching methods have been widely recognized as effective method for enhancing students' understanding of complex scientific concepts, including Genetics. According to Yagger and Akcay (2017), inquiry-based learning involves students actively investigating problems using scientific processes, fostering critical thinking and engagement. This method allows students to take on the role of scientists, enabling them to explore Biology topics, particularly Genetics, through hands-on experiences and problem-solving techniques (Banchi, 2020). In the context of Genetics, inquiry-based learning is particularly beneficial for topics such as Introduction to Genetics and Mendelian Inheritance, Molecular Basis of Inheritance, Non-Mendelian Inheritance, and Genetic Disorders. Through guided exploration, students develop explanations from their observations by integrating prior knowledge with new learning, which enhances their conceptual understanding (Banchi, 2020). For instance, in Mendelian inheritance, students can actively analyze genetic crosses and predict trait inheritance patterns, reinforcing their grasp of dominant and recessive traits (Akinyemi & Yusuf, 2019). Similarly, open inquiry enables students to investigate real-world genetic disorders, such as sickle cell anemia or hemophilia, by formulating their own research questions and conducting independent explorations (Oluwatayo & Olorundare, 2022).

Waddy (2014) classified inquiry teaching methods into four types: confirmation inquiry, structured inquiry, guided inquiry, and open/true inquiry. Confirmation and structured inquiry follow predetermined processes, while guided inquiry and open inquiry offer students more autonomy in their learning, making them particularly effective for teaching Genetics (Waddy, 2014; Roberts, 2020). Guided inquiry provides research questions and structured activities that direct students' exploration, while open inquiry allows students to formulate their own questions and independently investigate genetic phenomena. Jonassen, (2017) suggests that these methods enhance both academic achievements and retention by fostering deeper conceptual understanding and engagement.

Guided inquiry instructional method is characterized by a key feature: the teacher provides the materials and the problem to be investigated, while students devise their own procedures to solve the problem (Ogbaga, 2024). At this level, students are expected to be skillful enough to design their own investigations. However, the teacher remains a central figure, as they provide inquiry-driven questions to guide the learning process under the guidance of the teacher. Shuaibu (2017) opined that the guided inquiry method is a more effective teaching approach than the traditional lecture method, as it enhances students' academic achievements in science subjects. Similarly, Joda and Mohammed (2017) opined that the guided inquiry method is more effective than the expository method in enhancing cognitive achievement in Biology across different levels of scientific literacy. Likewise, Ibe (2013) asserted that the guided inquiry method significantly improves students' achievements in Biology. However, Ibe

(2013), noted that the expository method did not lead to significant retention of Biology concepts.

Guided inquiry enables students to explore the complexities of Mendelian inheritance patterns, the molecular basis of genetic variation, and the mechanisms underlying genetic disorders (Anderson & Hsieh, 2016). Guided inquiry involves students working through activities, problem-solving tasks, and laboratory experiments that promote active learning, helping students to not just memorize facts but to truly understand genetic principles (Ibrahim et al., 2018). Research by Adegoke and Uche (2017) supports this, showing that guided inquiry improves students' ability to understand genetic concepts such as dominant and recessive traits, key elements of Mendelian inheritance. Ibrahim (2018) found that students taught through guided inquiry performed better in assessments related to these concepts, particularly in understanding the relationship between genotype and phenotype. In the context of Adamawa State, where access to resources may be limited, guided inquiry can provide a cost-effective and engaging way to enhance students' understanding of Genetics. This method encourages students to take an active role in their learning, leading to higher academic achievements in complex topics such as the molecular basis of inheritance and genetic disorders.

Open inquiry relies on the teacher's ability to pose appropriate and challenging questions that guide students and stimulate their interest in learning (Shih, Chuang, & Hwang, 2018). The students are actively involved by generating their own inquiry questions, teachers play a supportive role in guiding decision-making and facilitating the inquiry process at every stage (Pedaste, 2015). The success of open inquiry depends on students' cognitive abilities, which teachers should understand to provide appropriate guidance and maximize learning outcomes (Bell, Smetana, & Binns, 2018). Unlike other inquiry methods, open inquiry is largely student-centered, with minimal teacher intervention. Students work collaboratively in groups, planning and executing all phases of their investigations independently. Similarly, Minner, Levy, and Century (2019) noted that this method promotes deeper engagement and long-term retention of scientific concepts. In this approach, students generate their own questions, design investigative methods, conduct experiments, and present their findings, making the learning experience more meaningful and interactive resulting in retention of facts.

Retention refers to how well students can remember and recall knowledge after a learning experience, and it is a fundamental concept in educational psychology and cognitive science (Brown, 2014). Retention of biological concepts is particularly crucial as students' progress into more advanced topics in Biology, such as Genetics. In this area, learners are expected to grasp complex ideas including gene expression, mutation, and the molecular mechanisms underlying inheritance. Guided inquiry has been shown to support retention by providing an interactive and engaging learning environment where students can revisit and explore these concepts through hands-on activities and collaborative discussions. This repeated and active engagement enhances long-term memory of the subject matter (Roberts, 2020). Jonassen (2017) emphasized that inquiry-based methods lead to better retention of scientific concepts because they involve deeper cognitive processing, allowing students to construct meaningful understanding. Supporting this, Akinyemi and Yusuf (2019) found that the use of guided inquiry in teaching Genetics significantly improved students' ability to recall and apply concepts such as genetic mutations and inheritance patterns. Thus, guided

inquiry not only facilitates comprehension but also reinforces biological knowledge in a lasting and meaningful way.

Studies by Jonassen (2017) highlight that inquiry-based methods improve students' ability to recall and apply scientific concepts over time. Roberts (2020) further emphasizes that the interactive nature of guided inquiry helps reinforce complex biological ideas, such as gene expression and genetic mutations. Additionally, Akinyemi and Yusuf (2019) found that guided inquiry notably improved students' ability to retain and apply key concepts in Genetics, reinforcing the effectiveness of this approach in enhancing both understanding and retention. Muhammad and Usman (2021) found that students who engaged in open inquiry learning retained more complex concepts in Genetics, such as the differences between Mendelian and non-Mendelian inheritance, compared to students taught using traditional methods by gender.

Gender refers to the socially and culturally constructed roles, behaviors, expressions, and identities associated with being male or female. In educational contexts, gender can influence how students engage with different teaching methods, including inquiry-based learning approaches (Aga, 2015). Gender differences in academic achievements under open inquiry methods can provide valuable insights into how to optimize learning methods. Omotayo and Alabi (2021) observed that male students often perform better in independent, inquiry-driven environments, while female students tend to benefit more from collaborative and supportive learning contexts. The collaborative nature of open inquiry allows female students to work together in exploring genetic concepts and solving problems, which can enhance understanding and retention. Ugochukwu et al. (2020) found that female students who engaged in group-based open inquiry learning demonstrated improved academic achievements and a better grasp of complex genetic topics such as disorders and mutations. For male students, the autonomy and self-direction encouraged by open inquiry may promote higher levels of engagement and success in investigative tasks. Recognizing these gender-based differences is essential for designing inclusive and effective teaching methods, particularly in senior secondary schools in Adamawa State.

Ajayi and Adedeji (2019) found that female students often perform better in structured learning environments, where clear guidance and support are provided. Olalekan et al. (2021) suggested that male students may perform better when they are given more freedom to explore and investigate concepts on their own.
Therefore, this research will address the challenges of poor academic achievements and retention of biological concepts among secondary school students in Adamawa State. By determining the effects of guided inquiry and open inquiry teaching method improving biology in senior secondary schools in Adamawa state.

Statement of the Problem

In recent times, a decline in students' academic achievement in Biology was observed. The Ministry of Education in (2016-2024) report on Adamawa state revealed that the academic achievement of students in the West Africa Senior School Certificate Examination in Biology conducted is below the average of (35%) percent (West Africa Examination Council, Chief Examiner's Report 2019-2022). In the year 2016 out of the total number of 15,546 candidates who sat for the biology examination in Adamawa state only 2,056 (13,23%) obtained credit passed and 13,490 (86.8%) was recorded failed, in 2017, 19.39% obtained credit passed while 80.6% was recorded failed, also May-June 2018 shows that (24.14%) obtained credit passed and (75.9%) was recorded failed, in 2019 (11.57%) obtained

credit passed and (88.4%) was recorded failed, also in 2020 (29.93%) obtained credit passed and (70.1%) recorded failed, in 2021 (23.34%) obtained credit passed and (76.7%) was recorded failed, also in 2022, (26.36%) obtained credit passed and (73.6%) failed, in 2023, (20.10%) obtained credit passed and (79.9%) failed, lastly in 2024, (35.54%) obtained credit passed and (64.7%) obtained failed in Biology.

These observations have generated concern among educational stakeholders within the state as to reason why students' achievement is poor in Biology examination. This may be attributed to teachers-parent relationship; poor teaching method such as lecture method may be likely be the causes of students' underachievement in the biology. The problem of this study is to investigate whether guided inquiry and open inquiry teaching methods may improve academic achievements and retention of secondary school students in Biology in Adamawa State.

Purpose of the study

The purpose of this study is to determine the effects of guided-inquiry and open-inquiry teaching methods on Biology students' academic achievements and retention in Senior Secondary Schools of Adamawa state, Nigeria. Specifically, the specific objectives of the study are to determine the:

1. Effects of guided-inquiry, open-inquiry and lecture methods on academic achievements of secondary school students in Biology in Adamawa State.
2. Effects of guided-inquiry, open-inquiry and lecture methods on academic achievements of secondary school students in Biology based on gender in Adamawa State.
3. Effects of guided-inquiry, open-inquiry and lecture methods on student's retention in Biology in Adamawa State.
4. Effects of guided-inquiry, open-inquiries and lecture methods on student's retention in Biology by gender in Adamawa State.

Hypotheses

The following null hypotheses are formulated to guide the study and also were tested at 0.05 level of significance.

$H0_1$: There is no significant difference between the mean achievements score of students taught Biology using guided-inquiry, open inquiry and those taught with lecture methods.

H_{02}: There is no significant difference between the mean achievements score of students taught Biology using guided-inquiry, open inquiry and those taught with lecture methods based on gender.

H_{03}: There is no significant difference between the mean retention scores of students when taught Biology using guided-inquiry, open inquiry and lecture methods.

H_{04}: There is no significant difference between the mean retention scores of students when taught Biology using guided-inquiry, open-inquiry and lecture methods by gender.

Methodology

This study adopted a quasi-experimental design involving pre-test, post-test, non-equivalent, and control group design as described by Frankel and Wallen (2003). The independent variables were the Guided Inquiry Method, Open Inquiry Method, and Lecture Method of teaching, while the dependent variable was students' academic achievement. Gender (male and female) served as the moderator variable. All groups were pre-tested, post-tested, and administered a retention test two weeks after the post-test. Since intact classes were used instead of random assignment, the design was categorized as

quasi-experimental. The study was structured using a 3 × 2 factorial matrix with three groups: Guided Inquiry (EG1), Open Inquiry (EG2), and Lecture Method (CG), each representing different instructional strategies for teaching Biology.

The study was conducted in Adamawa State, Nigeria, located in the Northeastern region with Yola as its capital. Created in 1991, the state comprises 21 local government areas with a population of about 3.7 million and a land area of 36,917 km². The people are predominantly engaged in agriculture, with distinct dry and rainy seasons. Adamawa State hosts several tertiary institutions such as Modibbo Adama University, Federal College of Education, and Adamawa State University, among others. The study specifically focused on Yola Education Zone, which includes Yola North, Yola South, and Fufore Local Government Areas. The zone was chosen due to its concentration of public secondary schools and accessibility for the research.

The population of the study consisted of 11,916 Senior Secondary II students offering Biology in 62 public secondary schools within Yola Education Zone. A total of 217 SS II students (126 males and 91 females) from three co-educational schools were sampled using a multistage sampling technique. The selection process involved simple random sampling to choose the education zone and purposive sampling to identify schools that met the criteria of having qualified Biology teachers and functional laboratories. Three schools GDSS Doubeli, GDSS Shagari, and GDSS Jambutu were randomly selected. Each school served as one of the treatment or control groups. Pre-test results analyzed using ANOVA showed no significant difference among the groups, confirming group equivalence before treatment, though the design remained quasi-experimental due to the absence of random individual assignment.

The instrument for data collection was a 50-item Biology Achievement Test (BAT) developed from the SS II Biology curriculum and validated by experts for face and content validity. The test covered topics such as Genetics and Mendelian Inheritance, aligning with the West African Senior School Certificate Examination syllabus. Reliability testing using the Kuder-Richardson 21 formula produced a coefficient of 0.81, confirming high reliability. Data collection lasted seven weeks, with pre-tests, instructional treatments, post-tests, and retention tests administered sequentially. Research assistants, trained to implement the respective teaching methods, conducted the lessons. Data analysis employed the Statistical Product Services and Solutions (SPSS, Version 25), with Analysis of Variance (ANOVA) for hypothesis testing at a 0.05 significance level.

Results and Discussion

Hypotheses Testing

Four hypotheses were formulated and were test using Analysis of Variance and

H_{01}: There is no significant difference between the mean achievements score of students taught biology using guided-inquiry, open inquiry and those taught with lecture methods.

Table 1: Summary of ANOVA Analysis of mean achievements score of students taught biology using guided-inquiry, open-nquiry and those taught with lecture method.

POSTTEST	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7304.147	2	3652.073	55.033	.000
Within Groups	14201.494	214	66.362		
Total	21505.641	216			

The result in Table 5 shows that there is a significant difference in the mean achievement scores of students taught biology using guided inquiry, open inquiry, and lecture methods. This is indicated by an F-value of 55.033 and a p-value of .000, which is less than the 0.05 level of significance. Based on this result, the null hypothesis which states that there is no significant difference between the mean achievement scores of students taught using the three instructional methods is rejected. To determine which specific methods differ, a post hoc test was presented on table 8 below.

Table 2 Summary of Post Hoc Tests Analysis of mean achievements score of students taught biology using guided-inquiry, open inquiry and those taught with lecture method.

(I) METHOD	(J) METHOD	Mean Difference (I-J)	Std. Error	Sig.
Guided Inquiry Method	Open Inquiry Method	3.62048*	1.41314	.039
	Lecture	13.54869*	1.37384	.000
Open Inquiry Method	Guided Inquiry Method	-3.62048*	1.41314	.039
	Lecture	9.92821*	1.30714	.000
Lecture	Guided Inquiry Method	-13.54869*	1.37384	.000
	Open Inquiry Method	-9.92821*	1.30714	.000

The result in Table 2 shows the outcome of a post hoc analysis comparing the mean achievement scores of students taught Biology using guided-inquiry, open-inquiry, and lecture methods. The analysis reveals that all pairwise comparisons between the teaching methods are statistically significant at the 0.05 level. Specifically, students taught using the guided inquiry method had significantly higher achievement scores than those taught using the open inquiry method (mean difference = 3.62, p = .039), and those taught with open-inquiry method performed better than those with lecture (mean differences =-9.93, p = .000).

H_{03}: There is no significant difference between the mean achievements score of students taught Biology using guided-inquiry and open inquiry by gender.

Table 3: Summary of ANOVA Analysis of mean achievements score of students taught Biology using guided-inquiry and open-inquiry by gender**.**

POSTTEST	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	144.311	1	144.311	1.452	.229
Within Groups	21361.329	215	99.355		
Total	21505.641	216			

The ANOVA analysis in table 3 which examine the mean achievement scores of students taught Biology using guided inquiry, open inquiry, and lecture methods by gender revealed no significant difference. This is shown by an F-value of 1.452 and a p-value of 0.229, which is greater than the alpha significance level of 0.05. This indicates that gender does not have a significant effect on the academic achievement of students when taught biology using any of the three instructional methods.

H_{04}: There is no significant difference between the mean retention scores of students when taught Biology using guided-inquiry, open inquiry and lecture methods.

Table 4: Summary of ANOVA Analysis of mean retention scores of students taught biology using guided-inquiry, open-inquiry and lecture method

RETENTION	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4243.448	2	2121.724	36.489	.000
Within Groups	12443.373	214	58.147		
Total	16686.820	216			

The results of the ANOVA analysis in table 4 indicate that there is a significant difference in the mean retention scores of students taught biology using the guided-inquiry, open-inquiry, and lecture methods. This is evidenced by the calculated F-value of 36.489 and a corresponding p-value of .000, which is less than the conventional significance level of 0.05. Therefore, the null hypothesis, which stated that there is no significant difference between the groups, is rejected. This suggests that the method of instruction has a significant impact on students' retention scores, and that at least one teaching method differs from the others in its effectiveness. Further analysis of Post Hoc test was presented on table 4.11 below to determine which specific teaching methods differ significantly from each other.

Table 5 Summary of Post Hoc Tests Analysis of mean retention scores of students taught biology using guided inquiry, open inquiry and lecture method

(I) METHOD	(J) METHOD	Mean Difference (I-J)	Std. Error	Sig.
Guided Inquiry	Open Inquiry Method	-1.16371	1.32278	.680
Method	Lecture	8.41675*	1.28600	.000
Open Inquiry Method	Guided Inquiry Method	1.16371	1.32278	.680
	Lecture	9.58046*	1.22356	.000
Lecture	Guided Inquiry Method	-8.41675*	1.28600	.000
	Open Inquiry Method	-9.58046*	1.22356	.000

The post hoc analysis in table 5 was conducted to determine where the significant differences lie among the three teaching methods: guided inquiry, open inquiry, and lecture. The results show that there is no statistically significant difference between the mean retention scores of students taught Biology using the guided inquiry method and those taught using the open inquiry method (p = .680), indicating that both inquiry-based approaches are similarly effective in enhancing student retention. However, the guided inquiry method resulted in significantly higher retention scores compared to the lecture method, with a mean difference of 8.42 (p = .000). Likewise, the open inquiry method also led to significantly higher retention scores than the lecture method, with a mean difference of 9.58 (p = .000). These result revealed that while there is no meaningful difference between the two inquiry-based methods, both are significantly more effective than the traditional lecture method in improving students' retention of biology content.

H_{04}: There is no significant difference between the mean retention scores of students taught biology using guided-inquiry, open-inquiry by gender.

Table 6: Summary of ANOVA Analysis of mean retention scores of students taught biology using guided inquiry and open inquiry by gender.

RETENTION	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	456.390	1	456.390	6.046	.015
Within Groups	16230.430	215	75.490		
Total	16686.820	216			

The result presented in Table 6 indicates that there is significant difference in the mean retention scores of students taught Biology using guided inquiry and open inquiry, based on gender. The ANOVA result revealed a between-groups sum of squares of 456.390 with an associated F-value of 6.046 and a significance level (p-value) of .015. Since the p-value is less than the alpha level of 0.05, it can be concluded that the observed difference in retention scores between male and female students is significant. This implies that gender plays a role in how students retain information when exposed to different teaching methods.

Summary of Major Findings/Results

Based on the analysis of the study, the following findings immerged:

1. There is significant difference between the mean achievements score of students taught Biology using guided-inquiry, open inquiry and those taught with lecture methods
2. There is no significant difference between the mean achievements score of students taught Biology using guided-inquiry and open inquiry by gender.
3. There is significant difference between the mean retention scores of students when taught Biology using guided-inquiry, open inquiry and lecture methods.
4. There is significant difference between the mean retention scores of students taught Biology using guided-inquiry, open-inquiry by gender.

Discussion of Findings

The findings of the study also revealed a significant difference in students' achievement scores across the three instructional methods guided inquiry, open inquiry, and lecture methods ($F = 55.033$, $p = .000$). Further post hoc comparisons indicated that students taught using the guided inquiry method achieved significantly higher scores than those taught using open inquiry and lecture methods. Additionally, students in the open inquiry group performed significantly better than those in the lecture group. These results demonstrate that the guided inquiry method is the most effective in enhancing students' achievement in biology among the three strategies investigated.

This finding strongly agrees with numerous earlier studies highlighted in the literature: Joda and Mohammed (2017) found that guided inquiry significantly enhanced biology achievement and retention among secondary school students in Yola, Adamawa State. Their findings closely align with the current results, confirming the superior effect of guided inquiry over conventional methods. Similarly, Bamidele (2015) reported that students taught Chemistry through guided inquiry scored higher than those taught through lecture and demonstration methods in Osun State. Margunayasa et al. (2019) also found that guided inquiry improved science learning outcomes in Singaraja City, particularly for students with strong cognitive styles, which supports the effectiveness of inquiry-based strategies in developing higher-order thinking and conceptual understanding. In

the same vein, Musa (2018) and Rashid (2020) confirmed that open inquiry strategies led to better performance than traditional methods, though not as impactful as guided inquiry. On the contrary, Sever and Guven (2014) reported some resistance to inquiry-based strategies among Turkish students, noting that effectiveness varied based on student readiness and teacher expertise. This offers a slight disagreement, suggesting context-specific limitations to the success of inquiry methods. The agreement of the current findings with most previous studies can be justified by several factors: Guided inquiry provides learners with a balance of structure and independence.

Unlike open inquiry, where students may feel overwhelmed, guided inquiry directs learning through questions, procedures, and teacher facilitation resulting in better cognitive processing and understanding. The effectiveness of guided inquiry may be explained by its ability to manage cognitive load. By providing frameworks and guidance, it avoids overburdening working memory compared to open inquiry, and contrasts sharply with the passive nature of lecture-based learning. Like many of the cited studies (e.g., Joda & Mohammed; Bamidele; Musa), the present research was conducted in a Nigerian secondary school setting with similar curricular content, learner backgrounds, and educational resources. This similarity supports the generalizability of the finding and explains why guided inquiry consistently outperforms traditional methods.

The finding also revealed that there is no statistically significant difference in students' achievement scores based on gender across the three instructional methods ($F = 1.452$, $p = 0.229$). This suggests that male and female students performed similarly, regardless of whether they were taught using guided inquiry, open inquiry, or lecture method. Gender did not play a significant role in determining achievement outcomes in this study. This finding is in agreement with Yakubu (2021) who found no significant gender difference in achievement among science students exposed to innovative teaching methods in Kogi State. This supports the present study's conclusion that instructional method, rather than gender, is the primary determinant of performance.

Similarly, John (2022) observed no meaningful gender differences in biology achievement when students were taught using open inquiry in Borno State. This further supports the idea that inquiry-based strategies are gender-neutral in their effectiveness. The findings disagreed with Joda and Mohammed (2017) who reported a significant gender difference in biology achievement following the use of guided inquiry, with male students slightly outperforming females. This contradicts the current result and suggests that gender effects may sometimes emerge depending on context or subject area. Also, Yusri, Albinus, and Ajat (2020) in noted that male students developed stronger critical thinking skills through guided inquiry, which may have translated into better performance.

This also diverges from the current result. Additionally, Nnorom (2017) found females to perform significantly better in biology when taught through guided inquiry and demonstration methods in Anambra State. The absence of a significant gender difference in this study can be justified on several grounds: The instructional methods were implemented uniformly for all students, regardless of gender. This may have created a level playing field, where both males and females had equal access to learning support, tasks, and engagement. Inquiry-based strategies such as guided and open inquiry promote independent learning and minimize teacher-centered biases, which

could have traditionally favored one gender over the other. This student-centered nature might explain the absence of gender disparity. In many parts of Nigeria, including Adamawa State, recent educational reforms and awareness campaigns have helped bridge the gender gap in STEM subjects. Increased encouragement for female participation in science could be contributing to this equal performance trend. The sample used in the present study may have consisted of males and females with similar academic backgrounds, motivation levels, and prior exposure to inquiry strategies, thereby reducing variability in achievement scores.

The results of the ANOVA showed that there is a statistically significant difference in retention scores among students taught using guided inquiry, open inquiry, and lecture methods ($F = 36.489$, $p = .000$). Post hoc comparisons revealed no significant difference between the guided inquiry and open inquiry groups, but both groups significantly outperformed the lecture method group. This indicates that inquiry-based teaching methods (guided and open) are more effective for enhancing students' retention of biology content than the traditional lecture method. This finding is consistent with several previous studies in the literature, supporting the superiority of inquiry-based instruction for retention: Musa (2018) found that students taught using open inquiry strategies in Kano State had higher retention scores in biology compared to those taught with conventional methods.

This aligns with the current finding that inquiry strategies improve retention. Rashid (2020) reported similar outcomes in Kaduna State, where students in the open inquiry group retained more biology knowledge over time than their counterparts in the lecture group. Bamidele (2015) in Osun State found that both guided inquiry and demonstration methods significantly enhanced Chemistry retention compared to conventional teaching, which supports the current result. Ghumdia (2016) also reported that inquiry methods significantly improved students' process skills and long-term memory of biology content in Biu, Borno State. Waziri (2021) in Gombe State found that students who learned genetics through inquiry-based learning demonstrated better conceptual understanding and retention.

The findings of the study disagreed with Unogu (2015), while acknowledging the effectiveness of guided-discovery, found that demonstration methods produced slightly better retention in accounting, possibly due to the nature of the subject requiring step-by-step procedural memory. This slight difference may be due to disciplinary variation rather than the method's effectiveness. John (2022) noted that gender differences interacted with method effectiveness in retention, though the present study found no such gender effect in retention among inquiry methods. The superior retention performance of students in the inquiry-based groups can be justified as follows: Both guided and open inquiry approaches actively involve students in the learning process. This active participation likely facilitates deeper cognitive processing, leading to better retention of concepts compared to the passive learning associated with the lecture method. Inquiry methods are grounded in constructivist theories of learning, where students build their understanding through exploration and experimentation. This promotes long-term memory retention, as students are more likely to remember what they discovered themselves rather than what they were simply told. Inquiry-based teaching often requires students to revisit, discuss, and apply concepts in different ways, reinforcing understanding and improving retention.

The lack of a significant difference between guided and open inquiry suggests that both methods are equally effective in promoting retention. This may be because

both allow students to investigate, experiment, and reflect core elements for long-term learning. Inquiry-based instructional methods are highly effective for enhancing students' retention of science content, especially in subjects like biology where conceptual understanding is critical. The findings justify the growing shift in science education from teacher-centered to student-centered approaches, especially in the Nigerian context where efforts are being made to improve STEM education outcomes.

The finding of the study revealed that there is a significant difference in retention scores between male and female students when taught biology using guided inquiry, open inquiry, and lecture methods ($F = 6.046$, $p = .015$). This finding indicates that gender has a significant effect on how students retain biology content, suggesting that male and female students respond differently to various instructional strategies in terms of retention. This finding of a gender-based difference in retention is supported by some studies and contradicted by others, reflecting a complex and sometimes inconsistent trend in educational research: John (2022) found that gender had a significant effect on retention in open inquiry-based biology instruction in Borno State. He reported that female students outperformed males in retention tasks, especially in topics requiring verbal explanation and conceptual understanding. Yakubu (2021), in a study on the influence of gender and innovative teaching methods in Kogi State, observed that gender moderated the effectiveness of inquiry-based methods, with females often showing higher retention in science topics. Nnorom (2017) in Anambra State also reported gender differences in the acquisition of biology process skills, which are closely tied to retention, especially when demonstration and guided inquiry were used.

This finding disagreed with Yusri, Albinus, and Ajat (2020) who found no significant gender difference in students' critical thinking and retention when exposed to guided inquiry learning, indicating that both male and female students benefited equally. Musa (2018) in Kano State also reported that gender was not a significant factor in biology achievement and retention when using open inquiry methods. Hashim, Ababkr, and Eljack (2015) in Jigawa State found that inquiry-based teaching methods improved performance and retention irrespective of gender, stressing that teaching strategy, not gender, was the critical determinant. The significant gender difference in retention observed in this study may be attributed to several contextual and pedagogical factors: In many Nigerian classrooms, gender roles and expectations can influence participation, confidence, and interest. For instance, in some communities, females may be more attentive, organized, or consistent in following up with classroom tasks, which can enhance retention.

In others, males may feel more confident engaging in hands-on inquiry activities, which could also boost retention. Research has shown that female students often prefer collaborative and verbal learning, while males may lean towards active experimentation. The nature of inquiry-based learning may favor one group over another depending on how it's implementedguided inquiry might support structured learners (often females), while open inquiry might benefit risk-takers (often males). Subtle teacher expectations and interaction styles may also impact how male and female students engage with the lesson. If the teacher unconsciously gives more attention or encouragement to one gender, it can influence their retention outcomes

Conclusion

Guided and open inquiry teaching methods were found to significantly enhance both academic achievement and retention of biological concepts, especially in complex topics such as Genetics. The results affirm that guided inquiry, in particular, provides the most substantial improvement in student outcomes, suggesting its priority use in Biology instruction. Furthermore, the study found no significant differences in achievement and retention scores between male and female students, indicating that both genders benefit equally from inquiry-based methods. This emphasizes the need for inclusive, gender-neutral classroom practices that offer all students equal opportunities to succeed in science education.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. Biology teachers should prioritize the use of guided inquiry as an instructional method to significantly enhance students' academic achievement.
2. Educators should provide equal academic opportunities and maintain gender-neutral instructional practices, as both male and female students benefit similarly from effective teaching methods.
3. The Ministry of Education and school administrators should train and support teachers in adopting guided and open inquiry strategies to improve students' retention of Biology content.
4. Teachers should continue to apply inclusive instructional strategies without gender bias, as both male and female students retain Biology content equally well.

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