
COMPARATIVE EFFECTS OF PROBLEM-BASED, INQUIRY-BASED AND LECTURE INSTRUCTIONAL STRATEGIES ON BIOLOGY STUDENTS' RETENTION IN DELTA STATE

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ABSTRACT

This study investigated the comparative effects of problem-based, inquiry-based and lecture instructional strategies on Biology students' retention in Delta State. Three research questions and three hypotheses guided the study. The study adopted the pre-test, post-test, planned variation quasi-experimental design. The population comprised 40,629 second year secondary school students (SS II) from public senior secondary schools in Delta State. The sample size comprised 318 SS II Biology students. The research instrument used for the study was the Biology Achievement Test (BAT). The face validity of the instrument, Biology Achievement Test, was done by three experts. The content validity was done with a table of specifications. The reliability of the instrument was done to determine its measure of internal consistency using KR20. The statistics that were employed for data analysis and testing of the hypotheses at 0.05 level of significance were mean, standard deviation, independent sample t-test, paired sample t-test and Analysis of Covariance (ANCOVA). The findings obtained in the study include that there is a significant effect of problem-based, inquiry-based and lecture instructional strategies on biology students' retention scores; and that there is a significant difference in mean Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies; the study also found that there is no significant difference in mean Biology retention scores between male and female students taught with problem-based, inquiry-based and lecture instructional strategies; and that there is no significant effect of interaction between sex and method of instruction on Biology students' retention. It was recommended, amongst other things, that curriculum planners and

school administrators should prioritize the adoption of problem-based and inquiry-based instructional strategies in Biology classrooms to enhance students' retention.

KEYWORDS: Problem-Based; Inquiry-Based; Lecture Instructional Strategy; Biology Students; Retention.

INTRODUCTION

The advancement of modern societies is largely driven by progress in science and technology. Recognizing this, nations across the world continue to prioritize the improvement of science education in order to enhance scientific literacy and technological competence among their citizens. The primary goal of science education is to equip individuals with the knowledge and skills required for scientific careers while also enabling them to think critically and participate meaningfully in societal development and decision-making processes.

Biology, as one of the core science subjects taught in Nigerian secondary schools, plays a vital role in science and science-related disciplines. It is the branch of science concerned with the study of living organisms and life processes. Biology covers a wide range of concepts, from microscopic cellular activities to large-scale ecological systems and global environmental changes. It examines essential life processes such as respiration, nutrition, growth, reproduction, excretion, and response to stimuli, which are common to all living organisms, including plants and animals.

The objectives of Biology education, as outlined in the National Policy on Education (FRN, 2014), include the development of practical laboratory and field skills, acquisition of meaningful scientific knowledge, and the ability to apply such knowledge to everyday life, particularly in areas such as health and agriculture. These objectives are intended to foster functional scientific attitudes and contribute to societal advancement through improved health outcomes, agricultural productivity, and human development (Ibe & Ukpai, 2013). Furthermore, Biology enables learners to better understand themselves and their immediate environment.

At the secondary school level, Biology education contributes significantly to national development by producing a scientifically literate and skilled workforce. It provides a foundation for students who aspire to pursue careers in fields such as medicine, nursing, pharmacy, and other health-related disciplines. As a key component of STEM education, Biology plays an essential role in promoting technological advancement and innovation.

Encouraging students to study Biology therefore helps to build a pipeline of skilled professionals capable of driving scientific and technological progress.

Despite its importance, students' retention in Biology at the secondary school level has remained a persistent concern. Evidence from WAEC Chief Examiners' Reports and related studies indicates that students' retention in Biology has consistently been low over the years (Ihejiamaizu & Ochui, 2019; Bichi et al., 2017). Data from WAEC and NECO further confirm that performance in Biology has remained unsatisfactory, with a significant proportion of students failing to achieve credit-level passes.

Statistical records from 2014 to 2022 reveal a consistent pattern of poor performance in Biology. In several years, less than half of the candidates obtained credit passes. For instance, pass rates were 33.9% in 2014, 28.6% in 2015, and 33.9% in 2016. Similarly, in 2017, only about 30% of candidates passed, while 70% failed. In 2018, approximately 33% passed, with 67% failing. Although there was a significant improvement in 2022, with pass rates rising to 75.50%, the overall trend still reflects longstanding challenges in students' retention and performance in Biology. These findings suggest that the issue of low retention has been persistent despite various interventions (Ali et al., 2014).

Several factors have been identified as contributing to poor retention in Biology. These include inadequate instructional materials, lack of laboratory facilities, insufficient textbooks, poor parental support, students' health challenges, and ineffective teaching methods (Dinah, 2013; Akinsanya et al., 2014; Manalanga & Awelani, 2014; Owino et al., 2014). Among these factors, instructional strategies have received particular attention, as they directly influence how students engage with and understand the subject.

The most commonly used method of teaching Biology is the traditional lecture method, often referred to as the "talk and chalk" approach. This method is teacher-centred, with the teacher serving as the primary source of knowledge while students play a passive role. Although widely used, the lecture method has several limitations. It promotes passive learning, limits student interaction, delays feedback, and does not adequately support the understanding of complex biological concepts that require practical or visual demonstration. Consequently, it may hinder students' retention and critical thinking abilities (Ochu & Haruna, 2015).

Given the limitations of the lecture method and the importance of Biology, there is a need to explore alternative instructional strategies that can enhance students' retention of biological concepts. This study therefore focuses on comparing the effectiveness of problem-based learning, inquiry-based teaching, and lecture methods in improving Biology retention among secondary school students.

Problem-based learning (PBL) is a student-centred instructional strategy that involves learning through the process of solving real-life problems. In this approach, students work collaboratively to identify what they need to learn, engage in self-directed study, and apply their knowledge to solve complex problems. PBL promotes critical thinking, problem-solving skills, and active engagement, as students participate in activities such as data collection, investigation, analysis, and reflection (Liu & Pasztor, 2022).

Research has shown that PBL enhances students' retention of Biology concepts by encouraging deeper cognitive processing and meaningful learning. By relating abstract concepts to real-life situations, students are more likely to retain knowledge over time (Funa & Prudente, 2021; Crespi et al., 2022). Collaborative learning within PBL also promotes peer interaction and knowledge sharing, which further strengthens understanding and retention. Additionally, the emphasis on critical thinking and self-directed learning helps students develop higher-order cognitive skills, leading to improved academic outcomes.

Another instructional strategy of interest is inquiry-based learning, which is grounded in constructivist principles. This approach allows students to actively construct knowledge through exploration, questioning, and investigation. It involves engaging students in scientific processes such as observation, experimentation, hypothesis testing, and critical analysis (Regina, 2021; Akpan, 2015).

Inquiry-based learning promotes active participation and encourages students to take responsibility for their learning. By engaging in hands-on activities and collaborative discussions, students develop deeper understanding and improve their retention of Biology concepts (Kareem, 2021; Ghumdia & Adams, 2023). The method also enables students to connect new knowledge with prior experiences, making learning more meaningful and memorable (Issaka, 2020; Kinyota, 2020).

Furthermore, sex may moderate the effectiveness of different instructional strategies. Research suggests that male and female students may respond differently to teaching methods due to variations in learning preferences and cognitive styles (Eka & Ede, 2023). While interactive strategies such as problem-based and inquiry-based learning may benefit both groups, female students may particularly thrive in collaborative and communicative learning environments, whereas male students may benefit from hands-on and structured learning experiences (Okwu & Akor, 2023; Fatokun & Eniayaju, 2023).

On the other hand, the lecture method may be more effective for students who prefer structured and teacher-directed instruction. However, it may limit engagement, particularly for students who benefit from interactive learning environments (Adigun et al., 2023;

Kareem, 2021). Therefore, the effectiveness of instructional strategies may vary depending on individual differences, making it necessary for teachers to adopt flexible approaches that accommodate diverse learning needs. A review of existing literature indicates a gap in studies that directly compare the effectiveness of problem-based, inquiry-based, and lecture instructional strategies on Biology retention within Delta State. This study therefore seeks to fill this gap by determining which instructional strategy is most effective in enhancing students' retention of Biology concepts in the study area.

Research Questions

The following research questions generated guided the study:

1. What is the difference in mean Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies?
2. What is the difference in mean Biology retention scores between male and female students taught with problem-based, inquiry-based and lecture instructional strategies?
3. What is the effect of interaction between sex and method of instruction on students' retention of Biology?

Hypotheses

The following null hypotheses formulated guided the study:

1. There is no significant difference in mean Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies
2. There is no significant difference in mean Biology retention scores between male and female students taught with problem-based, inquiry-based and lecture instructional strategies
3. There is no significant effect of interaction between sex and method of instruction on students' Biology retention

METHODS

This study employed a pre-test, post-test quasi-experimental design with planned variation, structured as a $3 \times 2 \times 3$ factorial design. The design incorporated three instructional strategies (problem-based, inquiry-based, and lecture methods), two categories of sex (male and female), and three testing phases (pre-test, post-test, and retention test). The population consisted of 40,629 Senior Secondary School II (SS II) students in public secondary schools in Delta State. A sample of 318 SS II Biology students was selected from six public secondary

schools, drawn across the three senatorial districts of the state. Two schools were selected from each district using a simple random sampling technique (balloting with replacement). The instrument used for data collection was the Biology Achievement Test (BAT), which was designed to measure students' achievement and retention in Biology. The test was adapted from past SSCE questions and covered topics already taught, including tissue and supporting systems, reproductive systems in invertebrates, ecological management, pollution, water and soil pollution, and pest and disease control. The BAT consisted of 50 multiple-choice items. To ensure validity, the instrument underwent both face and content validation. Three experts, one in Biology Education, one in Measurement and Evaluation, and one practicing Biology teacher, reviewed the test items in relation to the instructional plans, research questions, and hypotheses. Their feedback led to necessary revisions, mainly addressing typographical and structural issues. Content validity was further established using a table of specification to ensure proper distribution across cognitive levels and content areas. The reliability of the BAT was determined using the Kuder-Richardson Formula 21 (KR-21). The instrument was trial-tested on 50 students outside the study sample but within a similar population. The analysis yielded a reliability coefficient of 0.92, indicating a high level of internal consistency suitable for objective test items.

The treatment process was implemented in five phases.

Phase 1: Group Assignment: The six selected schools were randomly assigned to three instructional groups: problem-based, inquiry-based, and lecture method groups, with two schools in each category. Intact SS II classes within these schools were maintained for the study.

Phase 2: Training of Teachers (Research Assistants): Teachers assigned to the problem-based and inquiry-based groups were trained on the application of these instructional strategies. The training lasted three days, covering theoretical foundations, instructional procedures, and practical classroom application. Teachers in the lecture group were only briefed and provided with lesson plans aligned with the conventional lecture method.

Phase 3: Pre-testing: The BAT was administered as a pre-test to all groups prior to the intervention to establish baseline equivalence. The results were recorded for subsequent comparison.

Phase 4: Treatment Implementation: Students were taught using the assigned instructional strategies over the treatment period:

- **Problem-Based Strategy:** Students engaged in structured problem-solving processes involving understanding the problem, planning solutions, implementing strategies, and evaluating outcomes.
- **Inquiry-Based Strategy:** Instruction followed stages of planning, engagement, exploration, explanation, and elaboration, encouraging active investigation and knowledge construction.
- **Lecture Method:** Teaching followed a teacher-centred approach involving introduction, explanation, summary, evaluation, and assignment.

Phase 5: Post-testing and Retention Testing: An immediate post-test was administered after the treatment using a reshuffled version of the BAT to minimize test familiarity. A delayed post-test (retention test) was conducted four weeks later to assess long-term retention of learned concepts.

Several extraneous variables were controlled during the study. Initial group differences were addressed using analysis of variance (ANOVA). The Hawthorne effect was minimized by using regular classroom teachers. Interaction among participants was reduced by selecting schools located far apart. Test sensitization was controlled through time intervals between testing phases, and experimental bias was minimized by ensuring uniformity in instructional content and teacher qualifications. Data analysis was carried out using mean and standard deviation to answer research questions, while hypotheses were tested at the 0.05 level of significance. Independent and paired sample t-tests were used for selected hypotheses, while Analysis of Covariance (ANCOVA) was applied to others. All analyses were conducted using SPSS version 27. Decisions on hypotheses were based on p-values, with hypotheses rejected when $p \leq 0.05$ and retained when $p > 0.05$.

RESULTS

Research Question 1: What is the difference in mean Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies?

Table 1: Descriptive statistics of mean and standard deviation showing the mean comparison of Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies

Group	N	Mean	SD
Problem-Based	77	59.05	1.84
Inquiry-Based	146	57.92	0.79
Lecture Method	95	44.09	4.09

The data in Table 1 show the mean comparison of Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies. The result shows that students taught using the problem-based strategy recorded the highest mean retention score, with a mean score of 63.36, and a SD of 7.32. Students in the inquiry-based group also performed well, with a mean score of 62.18 and a SD of 7.92, but slightly lower than the problem-based group, but still higher than the lecture group with a mean score of 41.73 and a SD of 3.89.

Hypothesis 1: There is no significant difference in mean Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies

Table 2: ANCOVA analysis of the difference in mean Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies.

Tests of Between-Subjects Effects						
Dependent Variable: Retention						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	13956.448 ^a	3	4652.149	972.558	.000	.903
Intercept	7501.051	1	7501.051	1568.137	.000	.833
Pre-Test Achievement	414.114	1	414.114	86.573	.000	.216
Group	12973.032	2	6486.516	1356.043	.000	.896
Error	1501.992	314	4.783			
Total	944896.886	318				
Corrected Total	15458.440	317				

a. R Squared = .680 (Adjusted R Squared = .677)
 b. Computed using alpha = .05

Table 2 show a One-Way Analysis of Covariance (ANCOVA), which was conducted to assess the difference in mean Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies. The result shows that the computed F-value for the instructional group variable (problem-based, inquiry-based, and lecture methods) is 1356.043 with a p-value of .000, which is less than the significance level of 0.05. Hence, the null hypothesis is rejected, which means that there is a statistically significant difference in the mean Biology retention scores among students taught using the three different instructional strategies, after controlling for pre-test retention scores. The partial eta squared value of .896 reveals that approximately 89.6% of the variance in students' post-test retention scores can be explained by the instructional method used, suggesting a very strong effect. Because a significant difference was found, a post-hoc test was conducted to identify which groups differ from each other.

Table 3: Sheffe’s Post-hoc analysis of the difference in mean Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies.

Pairwise Comparisons						
Dependent Variable: Delayed Post-Test						
(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
Problem-Based	Inquiry-Based	1.990*	.322	.000	1.215	2.764
	Lecture	15.203*	.336	.000	14.393	16.013
Inquiry-Based	Problem-Based	-1.990*	.322	.000	-2.764	-1.215
	Lecture	13.213*	.296	.000	12.501	13.926
Lecture	Problem-Based	-15.203*	.336	.000	-16.013	-14.393
	Inquiry-Based	-13.213*	.296	.000	-13.926	-12.501

Based on estimated marginal means
 *. The mean difference is significant at the .05 level.
 b. Adjustment for multiple comparisons: Sheffe.

Table 3 shows a Post-hoc analysis of the difference in mean Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies. The result shows that students exposed to the problem-based strategy retained knowledge significantly better than those taught through the inquiry-based strategy, with a mean difference of 1.99 in favour of the problem-based group. Similarly, the problem-based group outperformed the lecture group with a substantial mean difference of 15.20, while the inquiry-based group also performed significantly better than the lecture group by 13.21 points. All differences were statistically significant at the 0.05 level.

Research Question 2: What is the difference in mean Biology retention scores between male and female students taught with problem-based, inquiry-based and lecture instructional strategies?

Table 4: Descriptive statistics of mean and standard deviation showing the comparison of Biology retention scores between male and female students taught with problem-based, inquiry-based and lecture instructional strategies.

Group	Sex	N	Mean	SD
Problem-Based	Male	34	58.88	1.99
	Female	43	59.19	1.72
Inquiry-Based	Male	77	57.86	0.80
	Female	69	57.99	0.77

Lecture	Male	48	44.52	3.54
	Female	47	43.65	4.57

The data in Table 4 show the mean comparison of Biology retention scores between male and female students taught with problem-based, inquiry-based and lecture instructional strategies. The result shows that in the problem-based instructional strategy, both male and female students recorded virtually identical retention scores, with only a 0.31 mean difference. In the inquiry-based instructional strategy, female students had a slightly higher retention score (by 0.13 mean score) than male students, while under the lecture method, male students again scored slightly higher than females (mean difference of 0.87).

Hypothesis 2: There is no significant difference in mean Biology retention scores between male and female students taught with problem-based, inquiry-based and lecture instructional strategies

Table 5: Independent sample t-test showing the difference in mean Biology retention scores between male and female students taught with problem-based, inquiry-based and lecture instructional strategies.

Group	Sex	n	Mean	SD	df	t-value	p	Decision
Problem-Based	Male	34	58.88	1.99	75	0.737	0.463	Ho6 Not Rejected
	Female	43	59.19	1.72				
Inquiry-Based	Male	77	57.86	0.80	144	0.948	0.344	
	Female	69	57.99	0.77				
Lecture	Male	48	44.52	3.54	93	1.030	0.306	
	Female	47	43.65	4.57				
$\alpha = 0.05$								

Table 5 shows an independent samples t-test, which was used to assess the difference in mean Biology retention scores between male and female students taught with problem-based, inquiry-based and lecture instructional strategies. The result shows that for the problem-based group, the t-value is 0.737 with a p-value of 0.463; for the inquiry-based group, the t-value is 0.948 with a p-value of 0.344; and for the lecture method group, the t-value is 1.030 with a p-value of 0.306. All p-values are greater than the significance level of 0.05. Hence the null hypothesis is not rejected, which means that there is no statistically significant difference in the mean Biology retention scores between male and female students taught using problem-based, inquiry-based, and lecture instructional strategies.

Research Question 3: What is the effect of interaction between sex and method of instruction on students' retention of Biology?

Table 6: Descriptive statistics of mean and standard deviation showing effect of interaction between sex and method of instruction on Biology retention.

Group	Sex	N	Mean	SD
Problem-Based	Male	34	58.88	1.99
	Female	43	59.19	1.72
	Total	77	59.05	1.84
Inquiry-Based	Male	77	57.86	0.80
	Female	69	57.99	0.77
	Total	146	57.92	0.79
Lecture	Male	48	44.52	3.54
	Female	47	43.65	4.57
	Total	95	44.09	4.09
Total	Male	159	54.05	6.68
	Female	159	54.07	7.30
	Total	318	54.06	6.98

Table 6 shows an effect of interaction between sex and method of instruction on Biology retention. The result shows that both male and female students benefited equally from the problem-based and inquiry-based strategies, and both had lower retention scores under the lecture method. Therefore, instructional method, not students' sex, appears to be the main determinant of retention outcomes in this study.

Hypothesis 3: There is no significant effect of interaction between sex and method of instruction on students' Biology retention

Table 7: ANCOVA analysis of the effect of interaction between sex and method of instruction on Biology retention

Tests of Between-Subjects Effects						
Dependent Variable: Delayed Post-Test						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	13975.203 ^a	6	2329.200	488.379	.000	.904
Intercept	7444.130	1	7444.130	1560.859	.000	.834
Pre-Test Achievement	412.758	1	412.758	86.546	.000	.218
Group	12902.087	2	6451.044	1352.632	.000	.897
Sex	.076	1	.076	.016	.899	.000
Group * Sex	18.480	2	9.240	1.937	.146	.012
Error	1483.237	311	4.769			
Total	944896.886	318				
Corrected Total	15458.440	317				

a. R Squared = .681 (Adjusted R Squared = .675)
 b. Computed using alpha = .05

Table 7 show a Two-Way Analysis of Covariance (ANCOVA), which was conducted to assess the effect of interaction between sex and method of instruction on Biology retention. The result shows that $F(6, 318) = 1.937$, $P > 0.05$ level of significance. The null hypothesis is, therefore, not rejected, which means that there is no significant effect of interaction between sex and method of instruction on students' Biology retention.

DISCUSSIONS

The first finding shows that there is a significant difference in the mean Biology retention scores among students taught with problem-based, inquiry-based and lecture instructional strategies. This finding suggests that the type of instructional strategy employed significantly affects how well students retain biological knowledge over time. Specifically, students who were taught using problem-based and inquiry-based strategies retained more content compared to their peers taught through the lecture method. This finding indicates that active and student-centred instructional methods not only improve immediate academic performance but also enhance long-term memory and understanding. The higher retention observed in the problem-based and inquiry-based groups could be attributed to the active engagement these methods promote. Problem-based learning often requires students to apply knowledge in solving real-life problems, while inquiry-based learning encourages exploration, questioning, and discovery. These forms of deep learning help students to internalize content meaningfully, making it easier to recall later. In contrast, the lecture method, which largely depends on passive listening, often results in shallow learning, limiting the extent to which students can retain information. The above finding aligns with Olayemi and Bello (2023), who reported that students exposed to inquiry-based and problem-solving methods exhibited significantly higher retention in biology compared to those taught via traditional lecture. The finding also confirms the finding of Usman and Eze (2021), which revealed that retention is enhanced when learners are actively involved in constructing their knowledge, rather than merely receiving it from teachers.

The second finding shows that there is no significant difference in mean Biology retention scores between male and female students taught with problem-based, inquiry-based and lecture instructional strategies. This finding suggests that sex does not influence students' ability to retain biological concepts over time when exposed to various instructional approaches. This implies that both male and female students possess comparable cognitive abilities in retaining learned content, provided that the instructional methods employed are effective and inclusive. This outcome may be explained by the fact that problem-based and

inquiry-based instructional strategies promote deep learning and long-term understanding through active engagement, critical thinking, and collaborative problem-solving approaches that equally benefit both sexes. Additionally, retention in learning is often linked to the quality of teaching, the nature of instructional materials, and the learner's level of engagement, rather than sex. Since all students were exposed to the same content, duration of instruction, and assessments, their retention abilities were likely influenced more by these uniform conditions than by sex differences. The above finding is in line with Olarewaju and Musa (2022), who found no significant sex disparity in students' retention of biology concepts following the application of constructivist teaching strategies. The finding also agrees with Agboola and Owolabi (2021), who reported that both male and female students retained scientific knowledge equally when taught using active learning techniques such as inquiry and problem-based learning.

The third finding shows that there is no significant effect of interaction between sex and method of instruction on students' Biology retention. This finding suggests that students' ability to retain Biology knowledge over time was not influenced by a combination of their sex and the type of instructional strategy used. Whether students were taught using problem-based, inquiry-based, or lecture methods, both male and female learners demonstrated similar retention capabilities. This indicates that retention of Biology concepts is more dependent on the nature and quality of instruction rather than on sex-based learning differences. One possible explanation for this outcome is that instructional methods like problem-based and inquiry-based strategies inherently promote long-term retention through active engagement, critical thinking, and practical application of knowledge. These strategies enhance memory by making learning experiences meaningful and student-centred, which benefit both males and females equally. Furthermore, the increasing push for sex-inclusive teaching practices in education may have minimized traditional disparities in educational outcomes between male and female students. The above finding supports the study of Arowolo and Akinsola (2021), which found that sex had no moderating effect on the retention of scientific knowledge among secondary school students taught using active learning strategies. The finding also aligns with Ezeh and Okeke (2022), who reported no significant interaction between sex and instructional method on retention in Biology, reinforcing the idea that well-structured instruction leads to equitable retention outcomes across sexes.

CONCLUSION AND RECOMMENDATIONS

Based on the findings of this study, it is concluded that the choice of instructional strategy plays a crucial role in enhancing students' retention in Biology. Specifically, student-centred approaches such as problem-based and inquiry-based methods were found to be more effective than the conventional lecture method, as they promote deeper understanding and sustained recall of concepts, thereby improving academic performance. The findings further revealed that students' sex does not significantly influence retention in Biology, indicating that both male and female students benefit equally from the instructional approaches employed. In addition, the absence of a significant interaction effect between sex and instructional method suggests that the effectiveness of these teaching strategies is consistent regardless of gender. Based on the findings of the study and the conclusion drawn, therefore, the following recommendations are made:

1. Biology teachers should consistently apply problem-based and inquiry-based approaches during classroom instruction, as these strategies have been shown to boost retention more effectively than lecture methods.
2. Sex should not be considered a limiting factor in instructional planning; teachers should apply the same effective strategies to all students while ensuring that classroom practices are inclusive and supportive of all learners.
3. Teachers should focus on implementing teaching strategies that benefit all learners equally and ensure that resources and instructional materials are equally accessible to both male and female students.
4. Policymakers and educational leaders should support sex-neutral instructional frameworks, emphasizing strategy effectiveness rather than sex considerations when designing science education curricula.

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