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Performance and Retention Outcomes of Secondary School Students learning Nutrient Cycle Using Biology Learning Activity Package (BIO-LAP)

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Abstract. This study examined the effectiveness of the Biology Learning Activity Package (BIO-LAP) as an instructional strategy for enhancing students' academic performance and retention in secondary school Biology in Nigeria. It also explored gender- and location-based differences in outcomes. A quasi-experimental research design was adopted, involving 157 senior secondary students drawn from both urban and rural schools. Participants were assigned to two groups: one taught using the conventional lecture method (n = 84), and the other instructed with the BIO-LAP (n = 73). Achievement and retention tests were administered, and data were analyzed using descriptive statistics and independent samples t-tests at a 0.05 level of significance. Findings revealed that students taught using BIO-LAP performed significantly better in both academic achievement and retention than those taught using the lecture method. Gender had no statistically significant effect on achievement or retention within the BIO-LAP group, indicating that the method is equally effective for male and female students. However, urban students significantly outperformed their rural counterparts in both achievement and retention, suggesting the influence of contextual factors such as access to learning resources and learning environment. The study concludes that BIO-LAP is a viable, student-centered instructional strategy capable of improving Biology learning outcomes. It recommends the adoption of BIO-LAP in science classrooms, continuous teacher training in activity-based instruction, and support for context-sensitive adaptations to bridge urban-rural disparities. The findings provide empirical backing for innovative pedagogies that align with national goals of improving STEM education quality and equity.

Keywords: Biology learning activity, LAP, science education, science teaching, biology education, retention, performance biology education

1. Introduction

The teacher's role in the teaching and learning process is critical, as the instructional strategies they adopt significantly influence students' academic performance and retention, particularly in Biology. The approach used in the classroom determines the extent to which students grasp and retain scientific concepts. Being a subject with extensive content linked to many domains, students often conceive it as complex and elaborate. Effective teaching of the subject requires that teachers' device strategies that encourage students to study the contents in an engaging way so as to incite interest and critical understanding. Therefore, teachers must implement appropriate learning strategies that stimulate students' interest and foster the acquisition of twenty first century skills, These abilities include critical thinking and problem solving skills; the capacity to find, analyze, synthesize, and apply knowledge to novel situations; interpersonal skills that allow people to work with others and engage effectively in cross-cultural contexts; self-directional abilities that allow them to manage their own work and complex projects; abilities to competently find resources and use tools; and the capacity to communicate effectively in many ways (Darling-Hammond et al., 2019). Science educators emphasize the need for teachers to use instructional methods that enhance students' conceptual understanding, promote scientific thinking, and develop problem-solving skills Rizwan et al., 2025; Udu & Eze, 2018; Munna & Kalam, 2021) and depart from the methods of teaching reminiscent of the era when learning was a mare acquisition of knowledge and teaching, giving and transmission of facts.

This is important considering the roles which Science play in driving industrialization, economic growth and overall national development of nations. A strong foundation in science education is essential for fostering self-reliance, innovation, and progress. In Nigeria, the National Policy on Education underscores the importance of science education in equipping students with the knowledge and skills necessary to function effectively in the modern world (FME, 2004). These knowledge and skills can only be effectively acquired through engagement in tasks that nurture self-regulation, resourcefulness, perseverance, and resilience, the ability to learn independently, curiosity, and creativity. Biology, when properly taught and

learned, enables students to address both personal and societal challenges with a mindset of problem-solving. Advancements in Biological studies have led to significant contributions in areas such as vaccine development, genetic engineering, disease control, environmental conservation, neuroscience, child growth and development, food security, population engineering and general human well-being (Adams et al., 2024; Costello et al 2023). Consequently, Biology is a prerequisite for various fields, including medicine, pharmacy, biotechnology, and agriculture, making it a popular subject among Nigerian secondary school students (Sallau et al., 2018).

In spite of this popularity, studies indicate persistent poor performance in the subject at the Senior Secondary Certificate Examination (SSCE) level in Nigeria (Bichi et al., 2019; Efe, 2017). These studies highlight a high failure rate among students in the examination, attributing it to teachers' predominant use of methods that are teacher-centered, limiting student interaction and engagement and promoting rote learning and memorization rather than deep understanding, making it ineffective for teaching abstract concepts in Biology. The lecture method, though advantageous for covering large content areas and managing large class sizes, does not intentionally target the nurturing of critical thinking, problem-solving, or long-term retention of concepts. This deficiency spells doom in this age where learning has been found to be socially constructed through effective classroom interactions and peer collaborations (Putera et al., 2024; Klein et al, 2023; Darling-Hammond et al., 2019).

Retention which is the ability to store and recall learned information, is crucial for academic success. Several factors influence retention, including teaching strategies, the nature of instructional materials, environmental conditions, and individual learning experiences. Research suggests that effective instructional strategies enhance retention by making learning more meaningful and engaging (Wushishi et al., 2017; James et al., 2024; Beers & Bowden, 2005; Nwankwo, 2025). However, studies have reported low retention of concepts among Nigerian secondary school students leading to poor performance in external examinations and have traced it to teachers' use of ineffective teaching methods (Onah et al., 2012; Ajayi & Ogbeha, 2017). The lecture method, commonly used in Biology classes, has been linked to students' inability to retain and apply learned concepts effectively (Abdulhamid, 2016). This calls for the adoption of more interactive and student-centered instructional approaches that enhance both performance and retention.

The Learning Activity Package (LAP) is an instructional strategy with origin traced to several group of researchers with interest in personalizing instruction. Smith (1972) had earlier completed a Learning activity package for personalizing instruction in language Arts and Mathematics in Alhambra city school. The strategy has gained traction as an effective strategy for improving learning outcomes (Maceiras, et al., 2025; Galos,2022; Ogoegbunam et al., 2020; Akpokiniovo, 2016; Njoku & Akamobi, 2015; Njoku & Akamobi, 2009; Odu & Eze, 2018; Ezeano & Odudu, 2015). BIO-LAP is a modified strand of LAP which is student-centered and activity-oriented in which the teacher facilitates learning of biology concepts by guiding students through a series of structured exercises (Catalan et al., 2023; Okunade et al., 2022; Ogoegbunam et al., 2020). Learning materials in BIO-LAP are broken down into small, sequential steps that progress from simple to complex concepts, allowing students to work at their own pace. This method actively involves students in the learning process through series of engagement and repetitive practice, thereby enhancing their understanding, retention, and overall academic performance. By shifting from traditional lecture-based teaching to the LAP approach, students may develop better scientific reasoning skills, leading to improved learning outcomes in Biology.

Another critical aspect of learning that warrants investigation in this study is the influence of gender on students' performance and retention. Research on gender differences in science education has yielded mixed findings. Some studies suggest that male students perform and retain information better than females (Ajayi & Ogbeha, 2017), while others indicate the opposite (Ajibola, 2014). These variations are often attributed to differences in exposure, learning experiences, and instructional strategies used in teaching Biology. Since there is no clear consensus on the relationship between gender and learning outcomes in Biology, further research is needed to determine whether BIO-LAP will present differential outcome for both gender while learning Biology.

Though LAP has been investigated for teaching Biology in Nigeria (Okunade et al., 2022), there is need to further investigate its effectiveness in fostering students' performance and retention of learned concepts by students in difference school locations among the different genders especially while learning the nutrient cycle. The objectives of this study are therefore to:

- determine if there is any significant difference in the performance and retention scores of biology students taught using the BIO-LAP and those taught using lecture methods
- determine if there is difference in performance and retention scores of male and female students taught using BIO LAP instructional strategy
- find out if there exist any significant difference in the performance and retention scores of urban and rural students taught using the BIO-LAP instructional strategy

1.1 Research Questions

To achieve the objectives of this study, the following research questions were addressed:

- How does the academic performance of students taught Nutrient Cycle using the Biology Learning Activity Package (BIO-LAP) compare with those taught using the lecture method?
- How does the retention of biology concepts by students taught Nutrient Cycle using the Biology Learning Activity Package (BIO-LAP) compare with those taught using the lecture method?
- What is the difference in academic performance between male and female Biology students taught Nutrient cycle using the Biology Learning Activity Package (BIO-LAP)?
- What is the difference in retention between male and female Biology students taught Nutrient cycle using the Biology Learning Activity Package (BIO-LAP)?
- Does the academic performance of Biology students taught Nutrient cycle using the Biology learning activity package (BIO-LAP) vary in urban and rural schools?
- Does the retention of learned concepts of Biology students taught Nutrient Cycle using the Biology Learning Activity Package (BIO-LAP) differ based on school location (urban and rural)?

1.2 Research Hypotheses

The following null hypotheses were tested in this study:

- There is no significant difference in the performance of Biology students taught Nutrient Cycle using the Biology Learning Activity Package (BIO-LAP) and those taught using the lecture method.
- There is no significant difference in the retention of concepts by Biology students taught Nutrient Cycle using the Biology Learning Activity Package (BIO-LAP) and those taught using the lecture method.
- There is no significant difference in the academic performance of male and female Biology students taught Nutrient Cycle using the Biology Learning Activity Package (BIO-LAP).
- There is no significant difference in the retention of male and female Biology students taught Nutrient Cycle using the Biology Learning Activity Package (BIO-LAP).
- There is no significant difference in the academic performance of Biology students in urban and rural schools taught Nutrient Cycle using the Biology Learning Activity Package (BIO-LAP).
- There is no significant difference in the retention of Biology students in urban and rural schools taught Nutrient Cycle using the Biology Learning Activity Package (BIO-LAP).

2. Theoretical Background

The effective instructional strategies that enhance students' learning outcomes draw from learning theories that emphasize active learning, knowledge retention, and cognitive development. Hence this study posits on constructivist, cognitive, and behaviorist learning theories. These theories provide a framework for understanding how students acquire, process, and retain knowledge when exposed to different teaching strategies and learning challenges.

According to the Constructivist Learning Theory (Piaget, 1950; Vygotsky, 1978) learners actively construct own understanding and knowledge through experiences rather than from passively received information. Piaget's (1950) strand of constructivism hinges cognition and learning on learners' active engagement in learning activities through which they are able to construct their own understanding while Vygotsky's (1978) social strand suggests that learning occurs best when students engage in tasks slightly beyond their current ability but within their potential to master with appropriate help or guidance. The Biology Learning Activity Package (BIO-LAP) fits into the constructivist framework with its student-centered, self-paced and individualized structured activities. Students have ample opportunities to engage with learning materials while searching for knowledge. The teacher's role thus shifts from that of an instructor to facilitating and guiding students through these individualized learning activities.

Sweller's (1988) Cognitive Load Theory (CLT) emphasizes the importance of managing working memory during learning. The theory explains that excessive cognitive load can hinder knowledge retention and problem-solving ability. It means that the traditional lecture method during which students receive large amount of information at once while passively listening, may overwhelm cognitively, leading to poor retention. In contrast, BIO- LAP deliberately breaks learning materials into smaller, manageable steps, allowing students to process information more effectively thus reducing cognitive overload. The sequential nature of BIO-LAP, which moves from simple to complex concepts, ensures that students gradually build their understanding without overwhelming their cognitive capacity. This structured learning approach is thus more likely to promote meaningful learning and enhances retention.

Also, underpinning this study is Skinner's (1954), Operant conditioning which emphasized the role of reinforcement in learning. Skinner (1954) argued that learning is strengthened through positive reinforcement, where desirable behaviors (such as correct responses and problem-solving skills) are rewarded, leading to increased motivation and engagement. The Biology Learning Activity Package (BIO-LAP) incorporates reinforcement/ immediate feedback as they progress through the structured tasks. This reinforcement mechanism helps students identify their mistakes, correct them, and retain knowledge more effectively. Additionally, LAP accommodates individual learning

styles, enabling both high-achieving and struggling students to benefit from a structured yet flexible learning process.

Also, the Dual Coding Theory (Paivio, 1971) suggests that information is better retained when presented through both verbal and visual formats. Traditional lecture methods primarily rely on verbal instruction, which may not cater for all learning preferences. However, the LAP approach integrates diverse instructional materials, such as diagrams, charts, interactive exercises, and hands-on activities, supportive of retention through multiple modes of representation. Retention, which is critical for academic success, is influenced by various factors, including the teaching strategies employed. Research has shown that ineffective instructional methods negatively impact students' ability to retain and apply learned concepts in real-life situations (Wushishi et al., 2017; Onah et al., 2012). Consequently, there is a need to find out if engaging BIO-LAP with its more interactive, student-centered approach will enhance both performance and retention.

Given the gaps in research and the need for improved instructional strategies, this study investigates performance and retention outcomes of secondary school students' using biology BIO-LAP in learning Nutrient Cycle. Additionally, the study will examine whether gender plays a significant role in students' learning outcomes when exposed to the BIO-LAP approach. The findings of this study provide empirical evidence on the effectiveness of BIO-LAP in enhancing Biology education and offer insights into its potential for addressing performance and retention challenges in secondary schools.

3. Methodology

This study employed a quasi-experimental research design to investigate the effect of the Biology Learning Activity Package (BIO-LAP) on secondary school Biology students' performance and retention in the Nutrient Cycle. The design is suitable because it allowed the researcher to examine cause-and-effect relationships without the full control of variables typically associated with true experimental designs. Specifically, the non-equivalent control group pre-test, post-test design was used, involving intact classes in experimental and control groups.

Senior secondary school two (SS2) Biology students in the 493 public secondary schools in Delta state, Nigeria were the target population. Only coeducational schools were used for the study. A multi-stage sampling technique was adopted in the study. Purposive sampling was used to select three local Government areas from the 25 in the state. Stratified sampling technique was employed to categorize the coeducational schools as urban and rural in the three local government areas earlier selected. Simple random sampling technique was then applied to select four schools (two urban and two rural) from each stratum. The intact classes were randomly assigned to treatment groups by ballot. Two of the schools were assigned to experimental treatment (BIO-LAP) while the other two were assigned to the control group (Lecture)

Two research instruments were developed and used for data collection by the researcher. They are the Biology Performance Test (BPT) which is a structured multiple-choice and short-answer questions designed to assess students' understanding of the Nutrient Cycle before and after the intervention. The second is the Biology Retention Test (BRT), a delayed post-test administered after a two- week period to measure students' retention of the concepts learned. Both instruments were subjected to content and face validation by experts in Biology education and measurement and evaluation. The instruments were administered to a select group of twenty SS2 students and the result were analyzed using KR 21 formula which yielded internal consistency reliability coefficient of 82 and 72 for the BPT and BRT respectively.

The study intervention lasted for six weeks, involving the following phases:

Week 1: Recruited Research Assistants who are the biology teachers in the schools were briefed and handed the developed lesson procedures for both intervention groups for study after very interactive session with the researcher. All terms and conditions for the exercise were also met.
Week 2: The researcher visited the participating schools on different days to supervise the administration of the Pre-test (BPT). Both groups took the BPT to establish baseline equivalence in form of pretest data.
***Week 3-6*:** The experimental group in the two schools were taught using the Biology Learning Activity Package (BIO-LAP), which includes structured, self-paced instructional materials with guided activities in water cycle, Nitrogen cycle, carbon cycle and macro and micronutrients required by plants. The control group was taught the same content using the lecture approach with the conventional teacher-centered approach.
Week 7: Post-test (BPT) was administered to the subjects of the two groups in all the participating schools.
Week 10: Retention Test (BRT) was administered. The BRT was used to collect retention data on the concepts taught.

Data generated from the study were cleaned, coded and analyzed using the descriptive (Mean, standard deviation and percentages) for the research questions while inferential statistics (t-test and ANCOVA) were employed to test for significance of differences in means being compared

3.1 Ethical Considerations

Formal permission was obtained in writing from authorities of schools selected for this study and the time for implementing the intervention was formerly allocated to the project such that it does not clash with other school subjects or activities. The teachers involved were also granted permission to participate in the project by their school heads. Also, students that participated in the study were informed about the purpose of the study and told about their right to withdraw at will anytime they choose. Their anonymity and confidentiality were also guaranteed. The researcher light refreshment to students during the intervention period.

4. Results

Research Question 1: How does the academic performance of students taught using the Biology Learning Activity Package (BIO-LAP) compare with those taught using the lecture method?

Table 1: descriptive statistics of teaching intervention

Intervention	N	%	Mean Achievement score	SD	STD Error
Lecture	84	53.5	47.39	8.59	.938
BIO-LAP	73	46.5	58.11	10.99	1.287

Hypothesis 1: There is no significant difference in the performance of Biology students taught using the Biology Learning Activity Package (BIO-LAP) and those taught using the lecture method.

Table 2: Independent t-test of significance of the difference in mean achievement scores due to teaching intervention

Group	N	Mean	SEM	df	T	Sig.(2-tailed)
Lecture	84	47.39	1.568			
BIO-LAP	73	58.11	1.592	155	-6.846	.000

This study investigated the impact of the Biology Learning Activity Package (BIO-LAP) on students' academic performance and retention in comparison to the traditional lecture method. The descriptive statistics (Table 1) show that students taught using BIO-LAP had a mean achievement score of 58.11 with a standard deviation of 10.99, whereas students taught using the lecture method had a significantly lower mean score of 47.39 with a standard deviation of 8.59. These figures suggest a difference in academic performance favoring the BIO-LAP group.

To test whether this difference is statistically significant, an independent samples t-test was conducted (Table 2). The results revealed a t-value of -6.846 with a p-value of .000, which is less than the 0.05 threshold for significance. This indicates that the difference in mean achievement scores between the two groups is statistically significant. Consequently, the null hypothesis which states that there is no significant difference in academic performance between the two groups is rejected. This finding supports the conclusion that students who were exposed to the BIO-LAP intervention performed significantly better than their counterparts who received instruction through the lecture method.

Hypothesis 2: There is no significant difference in the retention of Biology students taught using the Biology Learning Activity Package (BIO_LAP) and those taught using the lecture method.

Table 3: Independent sample t-test of the difference in retention due to teaching intervention

	Group	N	Mean	SD	SEM	df	t	Sig.(2-tailed)
Retention	Lecture	84	43.58	7.42	.810	155	-11.110	.000
	BIO_LAP	73	60.04	11.03	1.292			

Research Question 2 sought to examine how the retention of biology concepts by students taught using the Biology Learning Activity Package (BIO-LAP) compares with those taught using the traditional lecture method. The associated Hypothesis 2 stated that there is no significant difference in the retention of Biology students taught using the BIO-LAP and those taught using the lecture method.

To address this, an independent samples t-test was conducted. From Table 3, the students exposed to the lecture method (N = 84) had a mean retention score of 43.58 (SD = 7.42), while those taught using the BIO-LAP (N = 73) had a mean retention score of 60.04 (SD = 11.03). This indicates a mean difference of 16.46 points in favor of the BIO-LAP group. The result of the t-test further revealed that this difference was statistically significant with $t(155) = -11.110$, and a p-value = .000 ($p < .05$). Given this, the null hypothesis that there is no significant difference in retention between the two groups is rejected.

Hypothesis 3: There is no significant difference in the academic performance of male and female Biology students taught using the Learning Activity Package (LAP).

Table 4: t-test analysis on the mean performance scores of male and female students taught nutrient cycle using learning activity package method.

Group	N	Mean	SEM	Df	t	Sig(2-tailed)
Male (BIO-LAP)	35	24.50	.50	73	5.26	.01
Female (BIO-LAP)	38	24.20	.55			

P ≤ 0. 05 significance

The third research question investigated whether there is a significant difference in the academic performance of male and female Biology students who were taught using the Biology Learning Activity Package (BIO-LAP). The associated null hypothesis posited that no significant difference exists in the academic performance between male and female students when the BIO-LAP instructional approach is used.

The result from the independent samples t-test (Table 4) shows that male students (n = 35) had a mean achievement score of 24.50 with a standard error of the mean (SEM) of 0.50, while their female counterparts (n = 38) had a slightly lower mean score of 24.20 with an SEM of 0.55. The computed t-value was 5.26, with a corresponding p-value of 0.15, which is more than the 0.05 level of significance set for this study. The null hypothesis is not rejected, implying that there is no statistical significant difference in the academic performance of male and female students exposed to the BIO-LAP method of instruction. Specifically, male students performed marginally better than their female counterparts in terms of mean achievement score, although this difference is not substantial in magnitude.

Null Hypothesis 4: There is no significant difference in the mean retention scores of male and female students taught biology with learning activity package.

Table 4: t-test analysis on the mean retention scores of male and female students taught nutrition cycle using learning activity package method.

Group	N	Mean	SEM	Df	t	Sig(2-tailed)
Male (BIO-LAP)	35	24.90	.57	73	11.02	.101
Female (BIO-LAP)	38	22.70	.56			

P ≤ 0. 05 significance

The fourth hypothesis proposed that there would be no significant difference in the retention of male and female Biology students taught using the Biology Learning Activity Package (BIO-LAP). However, the result presented in Table 4 indicates a mean retention score of male students taught with BIO-LAP was 24.90 with a standard error of the mean (SEM) of 0.57, while that of their female counterparts was 22.70 with a standard error mean of 0.56. The computed t-value was 11.02 with a corresponding p-value of 0.101, which is significantly higher than the established 0.05 level of significance. This implies that the null hypothesis is retained, affirming that there is no statistically significant difference in the retention of biology concepts between male and female students when instructed using the Biology Learning Activity Package.

Null Hypothesis 5: There will be no significant difference in the academic performance of Urban and Rural students taught biology with learning activity package.

Table 5: t-test analysis of the mean achievement scores of Urban and Rural students taught nutrient cycle using learning activity package method.

Group	N	Mean	SEM	Df	t	Sig(2-tailed)
Urban (BIO-LAP)	40	29.12	.54	73	-.201	.822
Rural (BIO-LAP)	33	28.10	.53			

P ≤ 0. 05 significance

Null Hypothesis 5 stated that there is no significant difference in the academic performance of urban and rural students taught Biology using the Biology Learning Activity Package (BIO-LAP). The results from Table 5 clearly indicate a no statistically significant difference between the two groups. The urban students recorded a mean achievement score of

29.12 with a standard error of the mean (SEM) of 0.54, while the rural students recorded a minimally lower mean score of 28.10 with an SEM of 0.53. The computed t-value of -.201 with a corresponding p-value of 0.822 is far higher the 0.05 significance threshold, leading to the retaining of the null hypothesis.

Hypothesis 6: There will be no significant difference in the retention of Urban and Rural students taught biology with learning activity package.

Table 6: t-test analysis on the mean retention scores of Urban and Rural students taught nutrient cycle using BIO-LAP intervention.

Group	N	Mean	SEM	df	t	Sig(2-tailed)
Urban (BIO-LAP)	40	28.13	.52	73	11.10	.446
Rural (BIO-LAP)	33	27.90	.50			

$P \leq 0.05$ significance

Null Hypothesis 6 proposed that there is no significant difference in the retention of Biology concepts by urban and rural students taught using the Biology Learning Activity Package (BIO-LAP). the result in Table 6 shows a no significant disparity in retention scores. The urban group achieved a mean retention score of 28.13 (SEM = 0.52), while their rural counterparts had a mean score of 27.90 (SEM = 0.50). The computed t-value of 11.10 and a p-value of 0.446 ($p < 0.05$) provide compelling statistical evidence to retain the null hypothesis.

5. Discussion of Findings

The study investigated the performance and retention outcomes of students taught biology using the Biology learning activity package (BIO-LAP) and those taught using the traditional lecture method. The findings of this study revealed that there is significant difference in the performance of Biology students in favour of those taught nutrient cycle using Biology learning activity package instructional strategy. This finding aligns with the findings of Neboh (2012), Okunade et al., (2020), Ogoegbunam et al., (2020) and Galos (2022) which show that there is significant difference in the academic performance of students taught Biology using learning activity package and lecture. This significant difference finding suggest that the structured and individualized nature of Biology learning activity package provided students with necessary prompts needed to gradually process the information in bits as they engage in activities without the risk of cognitive overload often evident in the lecture method. These findings are also consistent with Akpokiniovo (2016) in who used LAP in Physics, Udu and Eze (2018) and Munna and Kalam (2021) that emphasized the importance of learner-centered instructional strategies in enhancing students' cognitive engagement, critical thinking and problem – solving which often times translate to high performance in tasks. Being a structured, activity-based, and interactive learner-centred approach, BIO-LAP, may have provided students with more opportunities to engage deeply with the content, collaborate, and construct knowledge, thereby improving their performance outcomes.

From a pedagogical perspective, the result underscores the value of adopting active learning instructional procedures like BIO-LAP in the Nigerian secondary school science curriculum. It aligns with call by the Federal Ministry of Education and curriculum reform advocates for a shift from passive to active learning strategies in science education. BIO-LAP offers a cost effective self-paced individualization of learning when compared with others like computer assisted instruction where availability of facilities might pose a hindrance

With reference to Hypothesis 2, this study found that students taught with BIO-LAP approach had a significantly more positive retention of biology concepts learned compared to the traditional lecture method group. The substantial mean difference implies that students taught through BIO-LAP not only learned more effectively but were also better able to retain biology concepts over time.

This study also revealed that there is a significant difference in the mean retention scores of Biology students taught nutrient cycle using learning activity package and those taught using lecture methods indicating a higher positive effect of BIO-LAP on students' ability to retain learned materials. This finding is in agreement with the findings of Ifeyinwa (2019) who carried out a similar study in Nsukka zone. It is also similar to Okunade et al., (2022) who investigated the effect of LAP on performance and retention of biology students in Ekiti state. This could be attributed to the breakdown of the learning task into small chunks so that learners were able to engagement and learn them in bits in the BIO-LAP instructional procedure. Similar result was also found by Ishaku (2019) who found similar positive results in favour of LAP.

The finding of this study (Hypothesis 3) revealed that there is no significant difference in the academic performance of male and female students taught biology with learning activity package. The finding of this present study is similar to Ifeyinwa (2019), and Okunade et al., (2022) who found no significant difference in the performance of males and females in the BIO-LAP group. This means that BIO- LAP is not gender discriminatory and supports learning and

retention of biology concepts by both boys and girls equitably. It could also be that BIO-LAP instructional method mediated for such variables as learning preferences, self-efficacy, and engagement levels that were previously reported as contributors to disparities under innovative pedagogies like activity-based learning of which BIO-LAP is subsumed. However, Akpokinovo (2019) found the contrary, having reported a better and higher performance for females than males in Ekiti Sate, Nigeria. Also, Ogoegbunam et al. (2020) reported a significant difference in the performance based on gender in Bichi Local Government area of Kano state. The similarity in the findings of Akpokinovo's (2019) and Ogoegbunam et al (2020) lies in their use of single sex schools which may have reduced the benefits which both genders were supposed to derive from interaction among the sexes.

In connection with hypotheses 5 and 6 which centred on performance and retention of Urban and rural students who used the BIO-LAP instructional procedure, the study reveals that there is significant difference in the academic performance and retention in favour of urban students. This finding is in line with that of Okorie and Ezeh (2016) which state that chemistry and mathematics students in urban schools performed better than their rural counterparts when taught with LAP method.

This finding echoes concerns raised in educational equity research in Nigeria and other developing countries, which highlight the persistent urban-rural divide in learning outcomes due to infrastructural, socio-economic, and pedagogical disparities (Uzor & Anene, 2019; Okebukola, 2020). This differential also may be explained by the lack of prior exposure of students in to hands-on activities in the rural schools. The teacher factor may have also contributed to this disparity as well as differences in learning environment and calls for better facilities and regular involvement of rural students in active learning with hands-on activities to get them familiar with individualized learning methods. However, the study disagreed with Udu and Eze (2017) who found no significant difference in the academic achievement of urban and rural students in organic chemistry taught with LAP. The finding shows that students' academic performance and retention will be greatly enhanced when innovative strategies like learning activity package are employed in the teaching and learning of science subjects.

6. Conclusion

Based on the findings of this study, the efficacy of BIO-LAP is affirmed. It not just in enhances short term academic performance but also in promotes long-term retention of biology concepts, which is crucial for future application and knowledge transfer. Its superiority as an instructional strategy in enhancing performance over the traditional lecture method of teaching Biology is exposed by this study

We also conclude that the use of innovative instructional procedures like BIO-LAP bridges the presupposed difference in performance and retention between males and females in science. It is thus gender inclusive as it supports the learning of biology by both genders

A significant difference in performance between urban and rural students suggests that contextual factors such as access to resources, teacher quality, and learning environments influence the effectiveness of BIO-LAP. This calls for adaptive strategies to support rural learners more effectively. It is also to be noted that rural schools persistently suffer poor teacher quality in science as well as non- availability of facilities for learning science and this has persistently affected rural students' outcome in science

7. Implications of the Study on Practice

The study has implication for the use of effective and innovative instructional methods that engage students actively in the learning of Biology. The traditional lecture method has proved inadequate for the teaching and learning of concepts in biology as it does not allow the students sufficient opportunity to reflect on learning materials so as to cognitively make personalized meaning out of it leading to shallow knowledge that are soon forgotten

While BIO-LAP has proven effective in enhancing learning and retention, the data suggest a need for differentiated implementation strategies that are responsive to students' backgrounds. Specifically, rural schools may require additional scaffolding, teacher capacity-building, localized content adaptation, and resource support to ensure that all learners benefit equitably. Training of pre-service biology teachers in the design and implementation of activity-based lessons.

The statistically significant difference in retention scores between urban and rural students highlights the importance of equity-focused educational planning. Ensuring that learning innovations like BIO-LAP are inclusive, adaptable, and context-sensitive is key to bridging learning gaps and fulfilling the goals of quality and equitable science education in Nigeria. Teachers of science and curriculum planners must take note of this and act accordingly.

Educational policymakers should design frameworks that encourage the integration and institutional support of activity-based learning strategies like BIO-LAP across Nigerian secondary schools. This policy reform should be accompanied with adequate provision of funds for development, production, and distribution of BIO-LAP materials, especially in under-resourced schools in rural areas.

There should also be a change in the evaluation system learning outcome to include students' dexterity and

ability to focus on tasks instead of the usual use of cognitive tests at all times. This will encourage engagement, participation and collaboration

8. Recommendations

This study recommends widespread adoption of BIO-LAP teaching technique in secondary schools to enhance engagement of students, interaction hands-on activities and individualization. This will improve the learning of biology and improve the retention of concepts and consequently achievement in final external examinations Educational policy makers should enforce its implementation as a pedagogic tool for learning biology

There is urgent need for regular training and capacity building of teachers on innovative pedagogies for teaching STEM subjects especially Biology. In this regard, Ministries of Education and professional teacher development agencies such as Science Teachers' Association of Nigeria (STAN) should organize regular workshops and training programs to equip Biology teachers with the skills required to effectively develop and implement BIO-LAP. Emphasis should be placed on lesson planning, facilitation of self-directed learning, and integration of hands-on activities.

The disparity in performance and retention of students in rural schools call for urgent addressing of the issues that affect science teaching in rural school. These include uneven distribution of materials for teaching and learning of science, teacher distribution and retention in rural areas, issues of infrastructure that make life comfortable rural / hazard allowance for science teachers. This will be incentives for willing teachers Integration into Teacher Education Programs:

The efficacy of BIO-LAP methodology demands that teacher education institutions and department include it in the curriculum of preservice teachers into their pre-service teacher training curricula, and teaching how the strategy can be enhanced from time to time, enabling future Biology teachers to gain early exposure and practice in activity-based and learner-centered instructional design.

The need for the provision of learning materials to rural school is here re-echoed. Such materials should be such that will be understandable to the students while they work as individualized learners such materials should include science kits, interactive modules and stimulating classroom environments suitable for implementation of BIO-LAP technique for learning

Education boards should establish a monitoring framework to track the implementation of BIO-LAP across schools, including periodic evaluations to measure its effectiveness, gather teacher feedback, and identify areas for improvement.

The use of BIO-LAP should be tailored to eliminate gender and location-based disparities, through inclusive content, gender-sensitive language, and equitable access strategies to ensure both male and female students, regardless of location, benefit equally. Continuous monitoring and feedback mechanisms should be established to assess the effectiveness of BIO-LAP and make necessary adjustments, ensuring sustained impact on student outcomes across diverse school contexts.

Further empirical studies should be encouraged to explore the long-term effects of BIO-LAP on different aspects of science education such as critical thinking, inquiry skills, and lifelong learning. This will inform ongoing improvement and scaling up of the approach.

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