Enhancing Biology Learning through Multimodal Representation: An Empirical Study on Senior Secondary Students' Achievement

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Abstract:- This empirical study explores the efficacy of multimodal representation in enhancing biology learning among senior secondary students. Multimodal representation integrates visual, auditory, and kinesthetic elements to convey biological concepts, aiming to cater to diverse learning preferences and deepen understanding. Through a quantitative analysis of learning outcomes, this research compares the academic achievement of students exposed to multimodal biology learning strategy against those using traditional lecture method. The study adopted quantitative non-randomised, pre-test, post-test quasi-experimental design in two non-equivalent intact classes to diagnose students learning ability on the use of multimodal representation strategy in biology classrooms. The intact classes were used to avoid disruption to classroom and school activities. Purposive sampling technique was adopted to select two public senior secondary schools in Education District V of Lagos State and 98 senior secondary II biology students were used as sample. The experimental group had 47 students while the control group had 51 students. The study used Biology Achievement Test (BAT) with reliability index of 0.86 as instrument to harvest data. Data analysis was done using pie chart, mean, standard deviation and analysis of covariance (ANCOVA) statistical tool. The result showed that there was statistically significant impact of multimodal representation on senior secondary students' achievement in biology, implying that the students from the experimental school treated with multimodal strategy out performed better than those from the lecture method group. However, a statistically significant difference was not found for gender of students in biology. The study provides evidence that the multimodal representation strategy is more beneficial for students' academic achievement in ecology than the lecture teaching approach. Recommendations were made to improve teaching and learning ecological concepts in biology for better achievement.

Keywords:- Achievement, Biology, Lecture Method, Multimodal Representation.

I. INTRODUCTION

Biology is one of the most important life science subject required by secondary students who aspire to study medicine and paramedical courses like pharmacy, agriculture, biotechnology and other biologically inclined subject. It is defined as a natural science that involves the study of life (living organisms), including their physical structure, chemical compositions, functions, development and evolution. Biology covers areas such as cytology, anatomy, physiology, ecology, genetics, Microbiology, taxonomy, and many others (Bello et al., 2020).

To study medically related courses and biologically allied courses in tertiary institutions, students need to develop scientific process skills and ethics to gain the requisite knowledge to achieve better in biology examination in the secondary schools (Dempster, 2023; Ezekiel, 2021). The relevance of biologically–based discipline to the socio-economic development of Nigeria made biology one of the most important subjects in the secondary school curriculum (Federal Ministry of Education, FME, 2014). Considering the inherent advantages of biology learning to the society, it is therefore imperative to motivate students in the secondary schools towards achieving goods result in their biology examinations. However, in spite of the huge societal benefits, efforts made by various government agencies in Nigeria, performance in Secondary School final year external examination has been poor (Ezekiel, 2021; WAEC, 2020).

The poor achievement has been linked to defective approach and wrong methodology during biology instructions, inadequate laboratory practical activities and field activities in ecology, poor spelling of biology technical terms and too many topics to cover (Eno, 2022; Raiyegbemi et al., 2020). Others include not making teaching and learning biology lively and interesting by teachers, very large classrooms, and Student poor attitude to learning (Chukwuka, 2023; Dangana & Mohammed, 2019). The West African Examinations Council Examiners Reports (2020; 2019; 2018) also made the following submissions on candidates weaknesses in WASSCE who wrote the biology 2 (essay): wrong spelling of some technical terms, poor drawing of diagrams, and inability to label the diagram

correctly, inability to use technical terms to describe some processes, inability to give title to the drawn diagrams, inability to compare biological processes appropriately, constructing of a food chain without showing the direction with arrow heads, poor response to questions on ecology and genetics, and poor expression in questions requiring explanation. All these factors played significant role that cumulated into underachievement in biology and the dwindling size of students studying biologically related courses in the university.

Teachers do not engage the students in activity based learning that involve active students' participation that evoke inquiry and problem solving to promote achievement (Oka & Samuel 2020; Abimbola, 2017; Etobro & Fabinu, 2017). Likewise, students were not made to engage in ecological practical on the field within the school premises to complement classroom lessons. Meanwhile, practical in ecology class help generate representations such as diagrams, graphical and mathematical calculations, which are various modes that help make learning more meaningful to the learners and help retention and achievement. Thus, good metacognitive strategies that will help students learn better should be used in biology class. The West African Examination Council (2020) suggested that teachers prepare students in practical biology especially in ecology and genetics where they need to interpret or draw diagrams, hence multimodal representations strategy.

Multimodal representations as a metacognitive strategy combined the use of more than one semiotic mode in the representations and or communications of biological knowledge, concepts and skills (Olukoya, 2023; Cress, 2014). Yesildag, (2016) reported that in the construction and sharing of scientific knowledge, text, graphics, pictures, diagrams, symbols, mathematical formula are commonly used due to their importance in the production and communication in science Thus, when multimodal representations are integrated into writing to learn activities, they serve as an alternative method of teaching and measurement of assessment for teachers as well as learning tools that activate students' cognitive abilities (Ainsworth et al., 2011).

The main goal of multimodal representation as related by Gilbert and Justi (2016) is to instill deep learning in students through the use of multimedia messages involving words, symbolic representations and others instead of only one mode of communication based on words. Multimodal representation play major role in the cognitive structure of an individual and how it selects and organises information, examines symbolic structures and maps (Bezemer et al., 2016). In addition, varieties of representations in visual and auditory dimensions enrich cognitive processes and trigger the processes of selection, organization and integration which in turn promote meaningful learning. Multimodal representation strategy when ploughed into ecological class with using the field practical as intervention helped concretize abstract concepts, dissolve conceptual misunderstanding, promote meaningful learning and

achievement, aid science process skills and scientific literacy. This will guide the student on development of science process skills. This is in line with the objectives of the National Biology Curriculum as follows: adequate laboratory and field skill, meaningful and relevant knowledge in biology ability to apply scientific knowledge to everyday life in matters of personal and community health and agriculture (FME, 2014).

In Biology classroom, teachers can use arrays of these modal representations to affect meaningful learning in areas of ecology and other aspects of biology are missing (Russell, 2014). Many biology teachers made use of one or two modes that may appeal to a particular student's learning styles and not all (Yeo & Nielson, 2020). Consequently, in area of ecology, measurement during field study, symbols representations, mathematical expressions and calculations, recording of ecological factors are some of the areas teachers should explore. The inability of teachers to fully engage students in activities that create real life experience leading to permanence in learning may lead to underachievement in our senior secondary school students' biology. Activity driven classroom will be germane to high achievement and not activity-deficient classrooms. It is therefore imperative for biology teachers to identity and map out various activities that require appropriate representations for his classroom lessons, which words or text, diagrams, symbols, pictures, for meaningful learning of concepts in ecology. Representations are very important to science learning as it widen learners learning scope in biology and diminish misconceptions in science and heighten scientific, literacy (Duman & Yakar, 2019).

➢ *Statement of the Problem*

Overtime, teachers' methodology and strategies are two key approaches that determine classroom success and high achievements of students in biology and science. Teachers' inability to incorporate activity-based teaching learning strategies to enhance students' reproduction of modal representations in biology class makes lessons uninteresting to students resulting in poor attitude and under achievement in biology. Representations such as diagram, graph, and mathematical calculations are depictions used to explain concepts in biology. The WAEC Chief Examiners Report (2020 and 2015) have pleaded with biology teachers to engage students in activity-based lessons, through field practical that can generate multimodal representations in ecology class to make lessons lively and to connect theory with practical. But, most time biology teachers give little or no time to ecology field practical as lessons were delivered with lecture method that is passive, teacher-centred and no not impact on students learning. Hence, this study investigated impact of multimodal representation strategy on senior secondary students' achievement in biology.

The following research questions guided the study.
- What is the effect of the treatment (multimodal representation and conventional method) on senior secondary school students' achievement in biology?

- What is the effect of gender on senior secondary school student achievement in biology when taught using multimodal representation strategy?
- What is the interaction effect of the treatment (multimodal representation, conventional method) and gender on senior secondary school students' achievement in biology?

➢ *Null Hypotheses*
- Ho_1: There is no statistically significant main effect of treatment (multimodal representation and lecture method) on senior secondary students' achievement in biology.
- Ho_2: There is no statistically significant main effect of gender on senior secondary school student achievement in biology when taught using multimodal representation strategy.
- Ho_3: There will be no statistically significant main effect of treatment (multimodal representation and lecture method) and gender on the senior secondary students' achievement in biology.

II. METHODOLOGY

➢ *Design and Sample*

This study adopted a non-randomised pre-test post-test quasi experimental design in two non-equivalent intact classes. The population of the study comprised all senior secondary biology students in public senior secondary schools in Education District V of Lagos State, Nigeria. The purposive sampling technique was used to select two schools. Purposive sampling technique because all the two schools possessed facilities such as botanical garden, school farm, grass lawn habitat, abandoned farmland for practical activities to generate representations such as diagram, mathematical calculations, and graphical representation during ecology lessons. Among the secondary schools, one was named experimental while the other was designated control. The experimental group had 47 students while the control group had 51 students in two intact classes of senior secondary two. In all, a total of 94 students participated in the study.

➢ *Instrumentation*

The instrument for the study was the Biology Achievement Test (BAT). The BAT was drawn from past National Examination Council (NECO) and the West African Examination Council (WAEC) questions between 2015 and 2020. The BAT contained four essay questions on ecology. The four questions covered ecological topics such as functioning ecosystem, growth rate, population studies, soil properties, and ecological factors. The questions were validated by test and measurement experts from WAEC and NECO and two experienced biology teachers who made sure that only questions that measured up to the standard were selected for the study. All the questions contain representations. The reliability of the instrument was established by the use of test-retest method and Pearson's Correlation coefficient to verify the reliability yielded a coefficient of 0.86.

➢ *Treatment Procedure*

The experimental school and control schools were pre-tested to understand their baseline before treatment. Thereafter, the treatment was carried out with the experimental group with the use of multimodal representation strategy in the school biology laboratory and the school farm/garden. The laboratory lessons was on ecological concepts such as functioning ecosystem, measurement of ecological factors, soil properties and other concepts conducted with the experiment group. The teacher introduced the topic and shared the lessons objectives and previous knowledge. The class only had normal class session in the laboratory where students worked in group on the concept taught. Each group cogitated and worked on the group assignment. The group's leader presented the findings to the class, question asked and answered proffered. Each lesson containing representation was highlighted such as how to use quadrat to sample population of small plants, tabulation of results obtained, and simple calculation. Students were drilled on how to draw what they observed, measurement of plant growth rate and plotting graph i.e graphical, pictorial and mathematical representation. The researcher's lesson plan and training manual was used as guides to teach the students. However, the control group had its classes in the classroom without any field practical as there was no activity that enhanced interest or generate representations. The lecture mode of instruction was utilized throughout the lesson duration. Post-test was administered to the groups after five weeks of treatment. The students' scripts were marked and collated after treatment.

III. RESULTS

The demographic data collected were analysed using pie chart, while mean and standard deviation were used to answer the research questions and inferential statistics of analysis of covariate (ANCOVA) for the null hypotheses at the 0.05 level of significance.
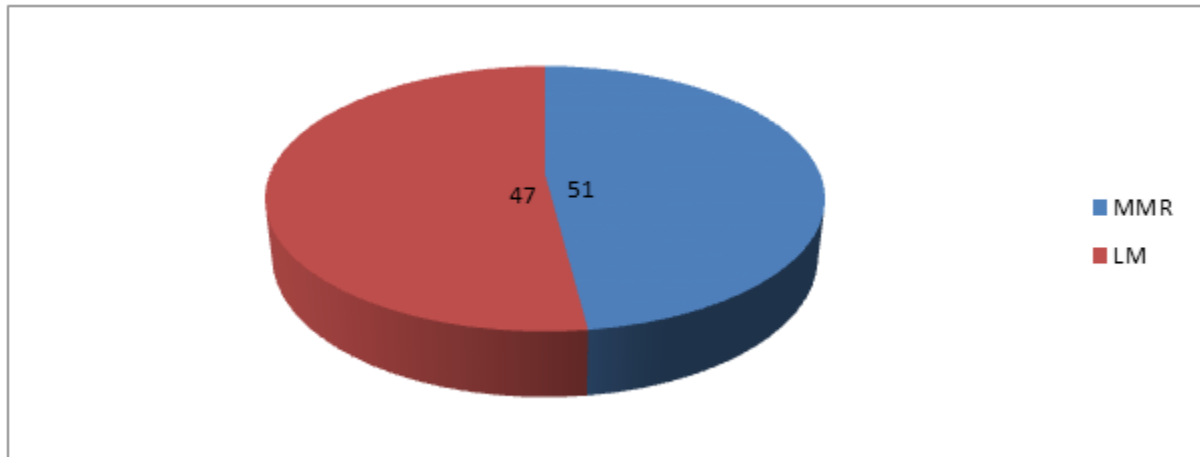
Fig 1 Participants' Groups

Figure 1 shows that 47 participants (33.3%) were experimental group (multimodal representation strategy, MMR) and 51 participants (36.2%) were in control group (lecture method, LM) out of the 98 students that participated in the study.
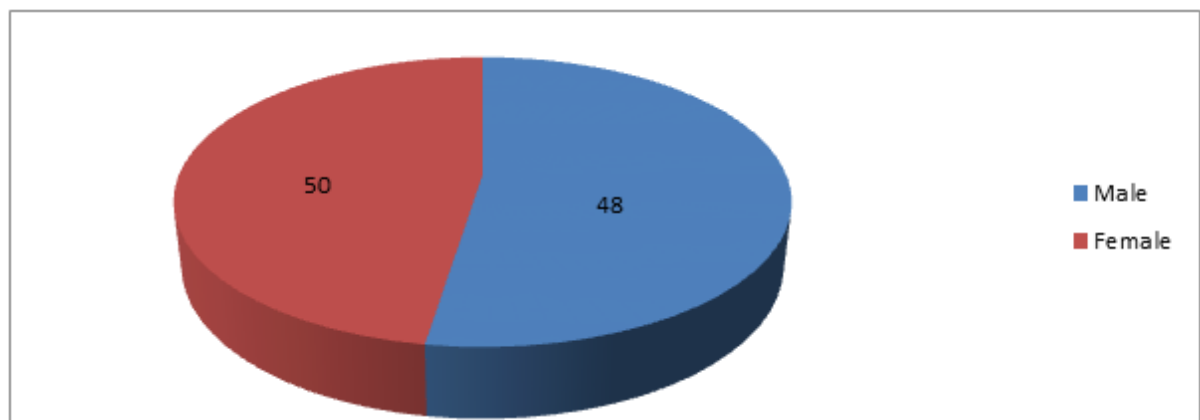

Fig 2 Participants' Gender

Also, Figure 2 reveals that 50 participants (51.0%) were males and 48 participants (49.0%) were females by gender out of the 141 participants in the study.

➢ **Research Question I:** What is the effect of treatment (Multimodal representation and conventional method) on senior secondary students' achievement in biology?

Table 1 Mean and SD of effect of treatment on student's achievement in biology

Groups	N	Mean		Mean Diff.	SD		SD Dif.
		Post-test	Pre-test		Post-test	Pre-test	
MMR	47	73.72	20.53	53.19	15.13	11.83	3.30
LM	51	31.82	10.53	21.29	11.82	10.53	1.29

The result revealed that students taught with multimodal representation group had the highest mean difference ore of 53.19 and standard deviation difference of 3.30; while the lecture group had a mean difference of 21.29 and a S.D difference of 1.29 in the post test. Therefore, the students in the treatment (multimodal) group achieved higher than the lecture or control group. To ascertain if this impact was significant, hypothesis one was tested at 0.05 level of significance.

H_{01}: There is no statistically significant main effect of treatment (multimodal representation and conventional method) on senor secondary students' achievement in biology.

Table 2 ANCOVA for Effect of Treatment on Students' Achievement in Biology

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	ηp^2
Corrected model	18236.782	20	911.839	8.964	.000	.599
Intercept	2555.434	1	2555.434	25.121	.000	.173
Groups	5731.742	2	2865.871	28.173	.000	.320
Error	12206.976	96	101.725			
Total	668495.000	98				

R Squared = .599 (Adjusted R Squared = .532)

The F-valued associated with post-achievement showed significant main effect of multimodal representation on senior secondary students' achievement in biology [$F(2,96)=28.17$; $p<0.05$]. The R Squared shows that the independent variables accounted for 59.9% of the variation in students' achievement in biology. The partial eta squared estimated indicates that the treatments accounted for 32.0% of the variance observed in the post achievement of students in biology. Therefore, the null hypothesis which state there is no statistically significant main effect of treatment on senior secondary students' achievement in biology is hereby rejected.

➤ **Research Question 2:** What is the main effect of gender on senior secondary students' achievement in biology when taught using multimodal representation strategy?

Table 3 Mean and SD of the Effect of Gender on Students' Achievement in Biology

Gender	N	Mean		Mean Diff.	SD		SD Diff.
		Posttest	Pretest		Posttest	Pretest	
Male	20	52.35	21.30	31.05	18.29	14.39	3.90
Female	27	43.70	19.96	23.74	12.46	9.75	2.71

Table 3 shows that male students in the MMR group a mean difference of 31.05 and SD difference of 3.90, while the female in the MMR group had mean difference of 23.74 and a SD difference of 2.7 in the post test and pre-test in ecology achievement test. The result this confirmed that the male in MMR group achieved better than the female students. Hypothesis two was tested to confirm the veracity of the research questions.

Ho₂: There is no statistically significant effect of gender on senior secondary students' achievement in biology when taught using multimodal representation strategy.

Table 4 ANCOVA for effect of Gender on Students' Achievement in Biology

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	ηp^2
Corrected model	18236.782	20	911.839	8.964	.000	.599
Intercept	2555.434	1	2555.434	25.121	.000	.173
Gender	214.434	1	214.434	2.108	.149	.017
Error	12206.976	45	101.725			
Total	668495.000	47				

R Squared = .599 (Adjusted R Squared = .532)

The F-value associated with post-achievement test in Table 4 shows no statistically significant main effect of gender on students' achievement in biology with [$F_{(2,96)}$= 2.11; p>0.05]. The R Squared shows that the independent variables accounted for 59.9% of the variation in students' achievement in biology. According to the partial eta squared estimate, the treatment only contributed 1.7% of the variance in the students' achievement in ecology. Therefore, the null hypothesis which states that there is no statistically significant effect of gender on senior secondary students' achievement towards biology when taught using multimodal representation methods is hereby not rejected.

> **Research Question 3:** What is the interaction effect of the treatment (multimodal representation, conventional method) and gender on senior secondary school students' achievement in biology?

Table 5 Mean and SD of Interaction Effect of Treatment and Gender on Students' Achievement in Biology

Dependent Variables	Groups	Gender	N	Mean	Std. Deviation
Post-Achievement	MMR	Male	20	59.45	6.78
		Female	27	62.15	9.35
	LM	Male	30	60.67	5.32
		Female	21	60.57	5.79

The result Table 5 on the interaction effect of treatment and gender on students' achievement, in ecology reveals that female students in the multimodal representation group had the best achievement in ecology with a mean of 62.15 and SD of 9.35. However, the students in the male students in the multimodal representation group had the least mean of 59.45 and standard deviation of 6.78 in the ecology achievement scores. To ascertain if the effect was significant, null hypothesis three was tested.

Ho₃: There is no statistically significant interaction effect of treatment (multimodal representation and lecture method) and gender on senior secondary students' achievement in biology.

Table 6 ANCOVA of Interaction Effect of the Treatment and Gender on Students' Achievement in Biology

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	ηp^2
Corrected model	18236.782	20	911.839	8.964	.000	.599
Intercept	2555.434	1	2555.434	25.121	.000	.173
Groups * Gender	136.863	2	68.431	.673	.512	.011
Error	12206.976	96	101.725			
Total	668495.000	98				

R Squared = .599 (Adjusted R Squared = .532)

Table 6 reveals no statistically significant interaction effect of treatment and gender on students' achievement in biology [$F_{(2,96)}$=.67; p>0.05]. The partial eta square which is 0.1also shows no interaction effect. There is no statistically significant interaction effect of the treatment (multimodal representation strategy and lecture method) and gender on senior secondary students' achievement in biology is hereby not rejected.

IV.   DISCUSSION OF FINDINGS

Result of hypothesis one in Table 3 showed significant effect of multimodal representation on senior secondary students' achievement in biology. The finding towed the line of Njoku and Mgbomo (2021) who found that field trip strategy and demonstration methods better promote students achievement. They reiterated that for good achievement and attitude to ecology teachers of biology should engage students in field studies along with class lessons. The result of the study also agreed with Mahmud et al. (2022), on the impact of ecological practical on students' field retention and academic performance in ecology among secondary school student when it was found that students taught using field strategies in ecology showed more positive interest and achieve considerably well compared to students taught ecology using lecture method. In terms of students' achievement, the revelation from the study conformed to the earliest studies carried out by Oka and Samuel (2020), on the effect of field studies along with class lesson in ecology helped promote student's interest and achievement in biology.

The findings from the study is also in agreement with the study carried out by Owiredu (2022), who reported that MMR used to teach organic chemistry in high school levels, promoted better achievement in chemistry compare to conventional method or lecture method. In a similar study conducted by Nawaz (2019), found that MMR instruction

improved students' learning which always results into better. Lending more credence to the findings above, Citra et al. (2019) in a study conducted to find out the effectiveness of MMR based teaching method to improve student self-efficacy and ability of physics problem solving, found that the MMR based instruction improved problem solving in physics and achievement. Thus, the liveliness and activity-driven lesson had a good impact on academic achievement since attitude is considered one of the contemporary factors that spur achievement. Hence the inclusion of practical field work was a boost that stimulates interest and achievement.

The result of hypothesis two in Table 4 reveals no statistically significant effect of gender on senior secondary students' achievement in biology when taught using multimodal representation strategy. This result aligns with the study of Njoku and Mgbomo (2021), who found that there was no significant effect of gender on student achievement in biology when taught using field study strategy. The result when compared with the study carried out by Okam and Zakari (2017), Showed reported that there was no significant impact of gender on senior secondary school student taught chemistry using laboratory teaching strategy in mastery of chemistry concept across gender in Katsina Metropolis in Kastina state Nigeria. The study is also in agreement with the study conducted by Tambaya et al. (2016) on pre-degree male and female student in Biology, Chemistry and Physics in Katsina state found that there was no effect of gender on student academic performance in pre-degree biology chemistry and physics academic performance But, in sharp contrast to the findings of the study, Hanson et al. (2020) found that there was a significant impact of gender on student achievement in science.

Result in Table 6 further reveals no statistically significant interaction effect of the treatment and gender on senior secondary students' achievement in biology. This result is in agreement with the findings of Nkok and Enang (2022), on the interaction effects of gender and teaching methods on students' interest, achievement and retention in sexual reproduction in plants. It was found that both male and female students did not respond to the treatment differently, thus gender is not a factor of determinant of achievement during the treatment. The result obtained also was in agreement with the study carried out by Ayanda et al. (2019), on the interaction effects of gender, score levels, analogies and concept maps on senior secondary school students' achievement in ecological concepts. The result obtained showed that there was no significant effect of treatments, gender and scores on students' achievement in ecology. Similarly, the result also resonates with the study conducted by Mwangi et al. (2019) who found that there was no significant interaction effect of gender on academic achievement of students in chemistry. The result just showed that gender interactions among students have no significant effects on their academic achievements.

V. CONCLUSION

The findings from the study revealed that students taught ecology by engaging in practical field activities to generate representations did better as the treatment made the lesson interesting, lively and help concretise learning and heighten achievement in biology compared to those students treated with conventional method. Active student-centred learning strategies that involve participation in science class is a good approach to learning biology. The study has contributed to the broader understanding of biology education by emphasizing the importance of showcasing real-word applications of ecological principles. Using appropriate interventions to generate representations helped widen students' knowledge, understanding of concepts, dissolve abstracts concepts, and reduce cases of conceptual misunderstanding.

RECOMMENDATIONS

- Incorporation of multimodal representation in biology education to enhance students' understanding, retention and spelling skills.
- Integration of multimodal representations, such as visual aids, diagrams, and interactive tools, in ecology lessons. This approach accommodates diverse learning styles, making the subject more accessible and appealing to students.
- Encouragement ongoing teacher training and professional development sessions to familiarize educators with effective implementation techniques of the and multimodal representation.

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