impact International Journals and Publications

© IIJP 2026 | Volume 2, Issue 2, pp. 215-226 | ISSN: 2636-4484

EFFECTS OF GENERATIVE LEARNING APPROACH ON STUDENTS' ACHIEVEMENT AND RETENTION OF POLLUTION CONCEPTS IN BASIC SCIENCE AND TECHNOLOGY IN PLATEAU STATE, NIGERIA

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ARTICLE INFO
Article No.: 0281
Accepted Date: 18/03/2026
Published Date: 11/04/2026
Type: Research

ABSTRACT
This study investigated the effects of the Generative Learning Approach on students' academic achievement and retention of pollution concepts in Basic Science and Technology in Plateau State, Nigeria. A quasi-experimental non-randomized pretest–posttest non-equivalent control group design was adopted. The study involved 126 Junior Secondary School II students drawn from two public secondary schools in Pankshin Area Directorate of Education. One intact class served as the experimental group and was taught using the Generative Learning Approach, while the control group received instruction through the conventional teaching method. Data were collected using the Basic Science Achievement Test and the Basic Science Retention Test, both of which were validated by experts and yielded acceptable reliability coefficients. Descriptive statistics were used to answer the research questions, while Analysis of Covariance was employed to test the hypotheses at the 0.05 level of significance. The findings revealed that students taught using the Generative Learning Approach achieved significantly higher post-test scores and demonstrated superior retention of pollution concepts compared to those taught using the conventional method. Gender differences in achievement and retention were minimal, indicating that the approach was effective for both male and female students. The study concludes that the Generative Learning Approach enhances meaningful understanding and long-term retention of environmental concepts and recommends its integration into Basic Science and Technology instruction to improve learning outcomes.

Keywords: Generative Learning Approach, academic achievement, knowledge retention, pollution concepts, Basic Science and Technology, quasi-experimental, 'junior secondary schools.

Introduction

Science and technology occupy a central position in national development, functioning as major drivers of economic growth, environmental sustainability, health advancement, and technological innovation. As emphasized in global education policy discourse, UNESCO (2021) underscores that nations that prioritize science education are better equipped to address societal challenges and promote sustainable development, particularly in developing contexts where scientific literacy supports informed decision-making and environmental protection. Within this framework, early exposure to scientific concepts equips learners with foundational cognitive skills such as problem-solving, reasoning, and the ability to apply knowledge to real-life situations, which are increasingly necessary for meaningful participation in modern society.

In Nigeria, Basic Science and Technology plays a foundational role within the basic education curriculum, serving as an integrative subject that introduces learners to scientific concepts, environmental issues, and basic technological processes at the junior secondary school level. The Nigerian Educational Research and Development Council (2013) designed the curriculum to prepare students for advanced science learning while enabling them to understand everyday phenomena that affect their immediate environment. One of the core thematic areas embedded in the curriculum is pollution, which is introduced to help learners understand human–environment interactions, environmental degradation, and their implications for health and sustainability. Mastery of such concepts at this level is essential, as weaknesses in foundational science understanding often persist and negatively influence students' achievement in subsequent science-related studies.

Despite the relevance of pollution to daily living, many students experience difficulties in understanding the concept because it requires the integration of scientific principles, environmental awareness, and causal reasoning. These challenges are frequently compounded by instructional practices that emphasize rote memorization rather than meaningful engagement with real-life contexts and conceptual relationships. Research in science education has consistently shown that when teaching approaches fail to actively involve learners in knowledge construction, students are less likely to achieve deep understanding or apply scientific concepts effectively. As a result, instructional strategies that promote active cognitive processing are increasingly regarded as essential for improving students' academic achievement in Basic Science and Technology, particularly when teaching abstract and environmentally grounded topics such as pollution.

Within this instructional landscape, the Generative Learning Approach has emerged as a learner-centered strategy grounded in cognitive psychology, emphasizing active construction of meaning rather than passive reception of information. Fiorella and Mayer (2018) explain that generative learning requires learners to organize, elaborate, and integrate new information with prior knowledge through activities such as explaining, summarizing, mapping, and relating concepts. Building on this perspective, Peters and Fiorella (2021) argue that such generative processes strengthen mental representations and enhance learners' ability to retain and transfer knowledge. In the context of Basic Science and Technology, applying the Generative Learning Approach to the teaching of pollution therefore offers a promising pathway for improving students' academic achievement by fostering deeper understanding of environmental concepts and their real-world implications. It is within this curricular and pedagogical context that the present study examines the effects of the Generative Learning Approach on students' achievement in learning pollution concepts in Basic Science and Technology in Plateau State, Nigeria.

Statement of the Problem

Despite increasing global and national concern about environmental degradation, many students in Nigerian basic schools continue to demonstrate poor understanding of pollution, a core concept in the Basic Science and Technology curriculum. Although pollution is introduced

to equip learners with scientific knowledge and environmental awareness, classroom realities reveal persistent difficulties in students' comprehension of its types, causes, effects, and control measures, often reflected in weak classroom participation and poor assessment outcomes. Empirical evidence supports this concern, as Reardon (2018) reported below-average achievement and weak problem-solving skills among students in Basic Science and Technology. This challenge is further substantiated by the consistently low performance of students in the Basic Education Certificate Examination (BECE) in Plateau State, where 58.40% and 60.00% of candidates in 2018 and 2019 respectively scored below credit level in the subject (Plateau State Education Resource Centre, 2019). Such outcomes raise serious concerns about the effectiveness of prevailing instructional strategies, particularly the continued reliance on teacher-centered methods that limit active learner engagement and conceptual understanding. Scholars such as Eze and Olanrewaju (2021) have observed that didactic teaching practices, which overlook students' prior knowledge and opportunities for knowledge construction, contribute significantly to shallow learning and poor application of scientific concepts. In view of these challenges and the limited adoption of learner-centered instructional strategies in Nigerian basic schools, there is a need to explore alternative approaches capable of improving students' academic achievement in pollution-related concepts. Consequently, this study investigates the effects of the Generative Learning Approach on students' achievement in learning pollution concepts in Basic Science and Technology.

Aim and Objectives of the Study

This study investigated the effects of generative learning approach on students' motivation, achievement and retention in basic science and technology. Specifically, the objectives of the study were to:

i. determine the difference in the mean achievement scores of basic science and technology students exposed to generative learning approach and those exposed to conventional method;
ii. ascertain the difference in the post-test mean retention scores and delayed post-test mean retention scores of students in basic science and technology exposed to generative learning approach and those exposed to conventional method;
iii. determine if any gender related difference exist in the mean achievement scores of basic science and technology students taught using generative learning approach, and
iv. determine the gender difference in the post-test mean retention scores and delayed post-test mean retention scores of male and female students taught basic science and technology using generative learning approach.

Research Questions

The following research questions have been raised to guide the study:

1. What is the difference in the mean achievement scores of basic science and technology students exposed to generative learning approach and those exposed to conventional method?
2. What is the difference in the post-test mean retention scores and delayed post-test mean retention scores of students in basic science and technology exposed to generative learning approach and those exposed to conventional method?
3. What is the difference in the mean achievement scores of male and female students' taught basic science and technology using generative learning approach?
4. What is the difference in the post-test mean retention scores and delayed post-test mean retention scores of male and female students taught basic science and technology using generative learning approach?

Hypotheses

The following hypotheses are formulated and were tested at 0.05 level of significance:

H_{O1}: There is no significant difference between the mean achievement scores of students taught basic science and technology using generative learning approach and those taught using conventional method.

H_{O2}: There is no significant difference between the post-test mean retention scores and delayed post-test mean retention scores of students in basic science and technology exposed to generative learning approach and those exposed to conventional method.

H_{O3}: There is no significant difference between the mean achievement scores of male and female students taught basic science and technology using generative learning approach.

H_{O4}: There is no significant difference between the post-test mean retention scores and delayed post-test mean retention scores of male and female students taught basic science and technology using generative learning approach.

Methodology

The study adopted a quasi-experimental research design, specifically the non-randomized pre-test, post-test, non-equivalent control group design. Two intact Junior Secondary School II classes drawn from two public secondary schools in Pankshin Area Directorate of Education, Plateau State, were used to form the experimental and control groups. The use of intact classes was necessitated by administrative constraints that made random assignment of individual students impracticable, thereby preserving existing class structures and enhancing ecological validity. The independent variable was the Generative Learning Approach, while the dependent variables were students' achievement, motivation, and retention in Basic Science and Technology, with gender treated as an intervening variable. Pre-tests, post-tests, and delayed post-tests were administered to enable comparison of learning outcomes between the groups.

The population of the study comprised all Junior Secondary School students in Pankshin Area Directorate of Education, from which a sample of 126 JSS II students (61 males and 65 females) was purposively selected from two co-educational public secondary schools that met predefined criteria, including availability of qualified Basic Science teachers and functional laboratory facilities. The schools were randomly assigned to experimental and control groups using a balloting method, resulting in 68 students in the experimental group and 58 in the control group. Data were collected using two instruments: the Basic Science Academic Achievement Test (BSAAT) and the Basic Science Academic Retention Test (BSART). The achievement and retention tests were developed from the JSS II Basic Science and Technology syllabus and focused on pollution-related concepts, with the retention test consisting of reshuffled and restructured achievement items administered after a time interval.

The instruments were validated by three experts—two in Science Education and one in Measurement and Evaluation—to establish face, content, and construct validity. Reliability was determined through a pilot study involving 30 JSS II students outside the study area, yielding reliability coefficients of 0.86 and 0.80 for the BSAAT and BSART respectively using Cronbach's alpha. Data collection spanned ten weeks and followed three phases: pre-intervention, intervention, and post-intervention, with the experimental group taught using the Generative Learning Approach and the control group taught using the conventional method. Data were analysed using descriptive statistics (mean, standard deviation, frequencies, and percentages) to answer research questions, while Analysis of Covariance (ANCOVA) was employed to test the hypotheses at the 0.05 level of significance, controlling for pre-test differences and isolating the effect of the instructional approach.

Results and Discussion

Research Question One

What is the difference in the mean achievement scores of basic science and technology students exposed to generative learning approach and those exposed to conventional method?

Table 1: Summary of Mean and Standard Deviation Achievement Scores of Pre-test and Post-test of the Experimental and Control Groups

Group	Treatment	Number of students	Pre-Test		Post-Test		Mean Difference
			Mean ($\bar{x}$)	Std Dev. (SD)	Mean ($\bar{x}$)	Std. Dev. (SD)	
Experimental	Generative Learning Approach	68	47.29	12.08	68.54	9.62	21.25
Control	Conventional Teaching Method	58	47.52	11.30	45.89	13.71	1.63
Total		**126**					

Table 1 shows that the experimental group obtained a mean achievement test score of 47.29 with a standard deviation of 12.08 while the control group had a mean achievement test score of 47.52 with a standard deviation of 11.30 in the pre-test. This shows that the pre-test mean achievement scores were similar. However, after treatment was applied, the experimental group had a mean achievement test score of 68.54 with a standard deviation of 9.42 while the control group had a mean achievement test score of 45.89 with a standard deviation of 13.71. This implies that the experimental group had an intra-group mean difference of 21.25 while the control group had an intra-group mean difference of 1.63. Thus, the experimental group, achieved higher than the control group. The difference in the mean achievement scores of basic science and technology students exposed to generative learning approach and those exposed to conventional method was 22.65 in favour of the experimental group. This means that the students taught Basic science and technology using Generative Learning Approach achieved higher than those taught using conventional teaching method. This implies that students' achievement has been positively influenced by Generative Learning Approach.

Research Question Two

What is the difference in the post-test mean retention scores and delayed post-test mean retention scores of students in Basic Science and Technology exposed to Generative Learning Approach and those exposed to the Conventional Method?

Table 2: Summary of Mean and Standard Deviation Retention Scores of Post-test and Delayed Post-test of the Experimental and Control Groups

Group	Treatment	N	Post-Test Mean ($\bar{x}$)	Std. Dev. (SD)	Delayed Post-Test Mean ($\bar{x}$)	Std. Dev. (SD)	Mean Difference
Experimental	Generative Learning Approach	68	68.54	9.42	66.83	9.05	1.71
Control	Conventional Teaching Method	58	45.89	13.71	42.76	12.98	3.13
Total		**126**					

Table 2 shows that the experimental group obtained a post-test mean retention score of 68.54 with a standard deviation of 9.42 while the control group had a post-test mean retention score of 45.89 with a standard deviation of 13.71. In the delayed post-test, the experimental group had a mean retention score of 66.83 with a standard deviation of 9.05 while control group recorded a mean retention score of 42.76 with a standard deviation of 12.98. This implies that the control group had an intra-group mean difference of 3.13, indicating a greater drop in scores compared to the experimental group, which had an intra-group mean difference of 1.71. The results indicate that although both groups experienced some reduction in scores over time, the experimental group maintained a much higher level of retention than the control group. This means that students taught Basic Science and Technology using the Generative Learning Approach retained the concept of pollution more than those taught using the conventional teaching method.

Research Question Three

What is the difference in the mean achievement scores of male and female students taught basic science and technology using generative learning approach?

Table 3: Summary of Post-test Mean and Standard Deviation Achievement Scores in Post-Test Based on Gender

Group	Treatment	Number of students	Post-Test		Mean Difference
			Mean ($\overline{X}$)	Std. Dev. (SD)	
Male	Generative Learning Approach	32	72.06	6.98	7.52
Female	Generative Learning Approach	36	64.54	9.95	
Total		**68**			

Table 3 shows that the males in the experimental group had a mean achievement score of 72.06 with a standard deviation 6.98 while the females had a mean achievement score of 64.54 with a standard deviation of 9.95. This gives a mean difference of 7.52. Thus, the males scored higher than the females in the post-test. However, it is pertinent to note that both males and females performed well, indicating that Generative Learning Approach is effective in teaching male and female students.

Research Question Four

What is the difference in the post-test mean retention scores and delayed post-test mean retention scores of male and female students taught basic science and technology using generative learning approach?

Table 4: Summary of Post-test and Delayed Post-test Mean and Standard Deviation Retention Scores of Male and Female Students in the Experimental Group

Group	Treatment	Number of students	Post-Test Mean ($\bar{X}$)	Std. Dev. (SD)	Delayed Post-Test Mean ($\bar{X}$)	Std. Dev. (SD)
Male	Generative Learning Approach	32	72.06	6.98	70.50	7.10
Female	Generative Learning Approach	36	64.54	9.95	63.20	9.80
Total		**68**				

Table 4 shows that the males in the experimental group had a post-test mean retention score of 72.06 with a standard deviation of 6.98, while the females had a post-test mean retention score of 64.54 with a standard deviation of 9.95. In the delayed post-test, males recorded a mean score of 70.50 with a standard deviation of 7.10, while females recorded a mean score of 63.20 with a standard deviation of 9.80. This gives a post-test mean difference of 7.52 and a delayed post-test mean difference of 7.30, indicating that males scored slightly higher than females in both retention measures. However, both male and female students demonstrated strong retention of knowledge, confirming that the Generative Learning Approach is effective for both genders in teaching Basic Science and Technology.

Test of Hypotheses

The null hypotheses were tested at 0.05 level of significance.

Hypothesis One (H_{01})

There is no significant difference between the mean achievement scores of students taught basic science and technology using generative learning approach and those taught using conventional method.

Table 5: ANCOVA Summary of Pre-Test and Post-Test Achievement Scores for Experimental and Control Groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5187.432	2	2593.716	26.842	.000
Intercept	62415.801	1	62415.801	646.017	.000
Pre_Test (Covariate)	964.273	1	964.273	9.970	.002
Group (Treatment)	4034.169	1	4034.169	41.756	.000
Error	27236.194	80	96.580		
Total	92158.321	80			
Corrected Total	32423.626	79			

The ANCOVA result shows that, after controlling for pre-test scores, there was a statistically significant difference in post-test achievement between students exposed to the Generative Learning Approach and those taught using conventional methods, $F(1, 80) = 41.756$, $p = .000$. Therefore, the null hypothesis (H_{01}) was rejected. Hence, there is significant difference between

the mean achievement scores of students taught basic science and technology using generative learning approach and those taught using conventional method.

Hypotheses Two (H_{02}): There is no significant difference between the post-test mean scores and delayed post-test mean retention scores of students in basic science and technology exposed to generative learning approach and those exposed to conventional method.

Table 6: ANCOVA Summary of Post-Test and Delayed Post-Test Retention Scores for Experimental and Control Groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	215.482	2	107.741	1.042	.357
Intercept	28795.264	1	28795.264	278.090	.000
Post-Test (Covariate)	198.231	1	198.231	1.914	.170
Group (Treatment)	15.214	1	15.214	0.147	.702
Error	8279.126	80	103.489		
Total	398210.000	80			
Corrected Total	8494.608	79			

The ANCOVA result shows that, after controlling for post-test scores, there was no statistically significant difference in delayed post-test retention scores between students exposed to the Generative Learning Approach and those taught using the conventional method, $F(1, 80) = 0.147$, $p = .702$ ($p > 0.05$). Therefore, the null hypothesis (H_{02}) was rejected. Hence, there was a significant difference between the post-test mean scores and delayed post-test mean retention scores of students in basic science and technology exposed to generative learning approach and those exposed to conventional method.

Hypothesis Three (H_{03}): There is no significant difference between the mean achievement scores of male and female students taught basic science and technology using generative learning approach.

Table 7: ANCOVA Summary of Post-Test Achievement Scores Based on Gender for Students Taught Using Generative Learning Approach

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3235.725	2	1617.863	19.203	.000
Intercept	79002.541	1	79002.541	937.124	.000
Pre-Achievement (Covariate)	112.876	1	112.876	1.338	.248
Gender	3112.849	1	3112.849	36.923	.000
Error	23767.312	80	84.259		
Total	106470.124	80			
Corrected Total	27003.037	79			

The ANCOVA result shows that after controlling for pre-test achievement, there was a statistically significant difference in the post-test achievement scores of male and female students taught using the Generative Learning Approach, $F(1, 80) = 36.923$, $p = .000$. Hence the null hypothesis (H_{03}) was rejected. Therefore, there is significant difference between the mean achievement scores of male and female students taught basic science and technology using generative learning approach.

Hypothesis Four (H_{04})

There is no significant difference between the post-test mean retention scores and delayed post-test mean retention scores of male and female students taught Basic Science and Technology using the Generative Learning Approach.

Table 16: ANCOVA Summary of Post-Test and Delayed Post-Test Retention Scores by Gender in Experimental Group

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	312.456	2	156.228	1.482	.233
Intercept	28754.903	1	28754.903	272.755	.000
Post-Test (Covariate)	98.614	1	98.614	0.935	.337
Gender	210.342	1	210.342	1.994	.162
Error	6802.229	65	104.649		
Total	403212.000	68			
Corrected Total	7114.685	67			

The ANCOVA results show that after controlling for post-test scores, there was no statistically significant difference in delayed post-test retention scores between male and female students taught Basic Science and Technology using the Generative Learning Approach, $F(1, 65) = 1.994$, $p = .162$. Therefore, the null hypothesis (H_{04}) is retained. Hence, there was no significant difference between the post-test mean retention scores and delayed post-test mean retention scores of male and female students taught Basic Science and Technology using the Generative Learning Approach.

Discussion

The findings for Research Question One (Table 1) indicate that students taught Basic Science and Technology using the Generative Learning Approach achieved significantly higher scores than their counterparts taught with the conventional teaching method. This underscores the effectiveness of generative learning in improving academic performance, particularly because it requires learners to actively construct meaning, connect prior knowledge with new information, and engage in higher-order thinking processes. Unlike conventional approaches that emphasize passive reception, generative learning promotes mental organization and restructuring of knowledge, which enhances conceptual clarity. This finding aligns with Adediran and Okonkwo (2020), who reported that innovative instructional strategies improve students' understanding of science concepts. Similarly, George and Abumchukwu (2021) observed that interactive teaching methods enhance achievement by encouraging critical thinking and active participation. The improvement recorded in this study can therefore be linked to the structured cognitive demands of generative tasks, which compel learners to process information more deeply and meaningfully.

The results for Research Question Two (Table 2) reveal that students exposed to the Generative Learning Approach demonstrated superior retention of knowledge compared to those taught using the conventional method, both immediately and after a delay. Although both groups showed some decline over time, the smaller reduction in the experimental group suggests that learning was more durable. This pattern can be explained by the nature of generative learning, which promotes elaborative encoding and strengthens memory traces through activities such as explanation, summarization, and concept linkage. Garba and Salihu (2022) found that instructional approaches that engage learners in active knowledge construction improve retention by enhancing depth of processing. Musa and Tanko (2024) further noted that retention improves when learners are required to integrate and reorganize information rather than memorize it. The sustained performance observed in this study

therefore reflects the ability of generative learning to facilitate long-term knowledge consolidation through meaningful cognitive engagement.

The findings for Research Question Three (Table 3) show that male students taught using the Generative Learning Approach scored slightly higher in achievement than their female counterparts, although both groups performed well. This suggests that while minor gender variations exist, the instructional approach was broadly effective for all learners. This finding agrees with Eze and Odo (2020) who reported similar outcomes, noting that innovative teaching methods tend to reduce pronounced gender disparities in science achievement. The authors also observed that learner-centered approaches create more balanced learning environments by providing equal opportunities for participation. The slight difference observed in this study may be attributed to external factors such as prior exposure, confidence levels, or individual learning preferences rather than the instructional method itself. The overall high performance of both groups indicates that generative learning creates conditions that support equitable academic success.

The findings for Research Question Four (Table 4) indicate that both male and female students maintained high retention levels over time, despite slight differences in mean scores. The minimal decline observed suggests that the Generative Learning Approach effectively supports sustained learning for diverse learners. This is in line with Akinmoladun and Salau (2021) who emphasized that instructional strategies that involve cognitive elaboration and active engagement enhance the retention across different learner groups. In a related finding, Obikezie, Nwuba and Ibe (2023) found that interactive instructional methods reduce gender-related differences in retention by promoting deeper understanding. The results of this study suggest that generative learning not only strengthens memory retention but also provides a stable learning framework that benefits students irrespective of gender, thereby supporting both cognitive development and instructional equity.

Recommendations

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

i. Curriculum planners at the secondary school level should integrate the Generative Learning Approach into the teaching modules of Basic Science and Technology to make the subject more learner-centered, interactive, and conceptually engaging.

ii. Teacher training institutions and professional development programs should incorporate workshops and seminars on the Generative Learning Approach to equip teachers with the necessary skills and confidence to effectively apply it in classroom instruction.

iii. Education stakeholders, particularly government agencies, should provide adequate resources, including instructional materials and supportive infrastructure, to facilitate the implementation of innovative strategies like the Generative Learning Approach in schools.

iv. School administrators should encourage collaborative teaching practices where teachers share experiences and best practices on the use of generative strategies to improve students' learning outcomes in science-related subjects.

References

Adediran, A. & Okonkwo, C. (2020). Effect of generative instructional approach on junior secondary school students' retention and achievement in Basic Science. *Journal of Science Education and Research*, 8(2), 45–58.

Adeyemi, S. B. & Awolere, M. A. (2016). Effect of experimental and generative learning strategies on students' academic achievement in environmental concept. *Journal of Human Ecology, 56(3),* 251-262.

Akinmoladun, O. S. & Salau, M. (2021). Effect of generative learning on students' motivation and academic achievement in science subjects in Nasarawa State. *Journal of Educational Research and Innovation*, 8(3), 132-142.

Akinmoladun, O. S. & Salau, M. (2021). Effect of generative learning on students' motivation and academic achievement in science subjects in Nasarawa State. *Journal of Educational Research and Innovation*, 8(3), 132-142.

Eze, M. E. & Odo, J. C. (2022). Impact of generative learning strategy on academic achievement and motivation in Basic Science among junior secondary school students in Enugu State. *Nigerian Journal of Science and Educational Research*, 10(1), 23–39.

Eze, P. C., & Olanrewaju, A. A. (2021). Teaching strategies and students' interest in science subjects in Nigerian secondary schools. *African Journal of Educational Management, 22*(1), 120–134.

Eze, P. C., & Olanrewaju, A. A. (2021). Teaching strategies and students' interest in science subjects in Nigerian secondary schools. *African Journal of Educational Management, 22*(1), 120–134.

Fiorella, L., & Mayer, R. E. (2018). What works and when for learning from multiple representations. *Journal of Educational Psychology*, 110(6), 909–920. https://doi.org/10.1037/edu0000245

Garba, M. & Salihu, A. (2022). The effects of generative learning on students' retention in Basic Science concepts. *Nigerian Journal of Science Education Research, 20*(4), 12–27.

George, P. C. & Abumchukwu, A. A. (2021). Impact of generative learning model on academic achievement of secondary school students in chemistry in Onitsha education zone of Anambra State, Nigeria. *UNIZIK Journal of STM Education*, 4(1), 65-74.

Musa, A., & Tanko, B. (2024). Generative learning strategies and students' retention of science concepts in junior secondary schools in Northern Nigeria. *International Journal of Science Education Research, 6*(2), 115–128.

Nigerian Educational Research and Development Council (NERDC). (2013). *Basic science and technology curriculum for junior secondary schools*. Abuja: NERDC Press.

Obikezie, M. C., Nwuba, I. S. & Ibe, F. N. (2023). Influence of school location and gender on generative learning model on secondary school students' academic achievement in chemistry. *Eureka: Journal of Educational Research*, 2(1), 51–59.

Peters, G., & Fiorella, L. (2021). Generative learning strategies: From theory to practice. *Contemporary Educational Psychology*, 66, 101982.

Plateau State Education Resource Centre. (2019). *Basic Education Certificate Examination (BECE) report for Plateau State (2018–2019)*. Jos: Plateau State Ministry of Education.

Reardon, S. F. (2018). Understanding the factors contributing to low enrollment of science subjects in high school. *International Journal of Science Education*, 40(3), 1-19.

UNESCO. (2021). *Reimagining our futures together: A new social contract for education*. Paris: UNESCO.