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ACTIVE RECALL AS AN ASSESSMENT STRATEGY FOR COGNITIVE RETENTION AND AFFECTIVE OUTCOMES IN STEAM EDUCATION

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Abstract

This study examined the effectiveness of active recall as a self-testing strategy for enhancing students' academic performance, retention, engagement, metacognitive awareness, and self-efficacy in Science, Technology, Engineering, Arts, and Mathematics (STEAM) subjects in South-South Nigeria. A quasi-experimental pretest–posttest non-equivalent control group design was employed using a sample of 120 senior secondary two students selected through purposive sampling. The experimental group received instruction integrated with active recall strategies, while the control group was taught using conventional methods. Data were collected using the STEAM Achievement and Retention Test (SART), Metacognitive Awareness Inventory (MAI), STEAM Self-Efficacy Questionnaire (SSEQ), and Student Engagement Checklist (SEC). Reliability coefficients ranged from 0.79 to 0.85, indicating high internal consistency. Data were analysed using mean, standard deviation, independent t-test, and Analysis of Covariance (ANCOVA). Results revealed that active recall significantly improved students' academic performance, retention, engagement, metacognitive awareness, and self-efficacy. The findings further indicated no significant gender differences, suggesting that the strategy is equitable across male and female students. It was recommended that active recall be integrated into classroom instruction, teacher training, and curriculum design to enhance long-term learning outcomes in STEAM education.

Keywords: Active recall, self-testing, cognitive retention, steam education, affective outcomes

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Introduction

The demand for 21st-century skills, particularly in Science, Technology, Engineering, Arts, and Mathematics (STEAM), has highlighted the need for evidence-based assessment strategies that support deep learning, long-term retention, and academic success. These disciplines are central to innovation, problem-solving, and national development. However, despite ongoing curriculum reforms and increased investments in STEAM education in Nigeria, student outcomes, especially in public secondary schools, remain below expectations (Udo & Ekong, 2020). This is consistent with Uko & Uko (2019), who argue that structured instructional assessment provides a foundation for improving both retention and affective outcomes in Nigerian secondary education.

Active recall, a cognitive strategy grounded in retrieval practice, has shown strong potential in addressing these learning challenges. Rather than passively reviewing notes, students using active recall attempt to retrieve information from memory, which strengthens neural pathways and deepens conceptual understanding (Dunlosky et al., 2013). This technique is particularly effective when combined with spaced repetition and self-testing, using tools like flashcards, low-stakes quizzes, or written recall exercises. These strategies have been found to improve not only retention but also problem-solving skills essential in STEAM subjects.

Beyond cognitive benefits, active recall also impacts affective and self-regulatory domains critical for success in STEAM education. Zepeda et al., (2019) see metacognitive awareness as the ability to monitor and regulate one's thinking, which is stimulated through retrieval practice as students evaluate what they remember versus what they forget. Self-efficacy, or the belief in one's ability to succeed, is enhanced when students experience repeated success through active recall, leading to greater persistence and resilience (Usher & Schunk, 2018). Similarly, according to Fiorella and Mayer, (2016), student engagement, across behavioural, emotional, and cognitive dimensions, is heightened by the active involvement that retrieval strategies demand.

Another important consideration is gender equity in STEAM education. Female students often report lower self-confidence in subjects like physics and engineering despite equal performance levels. Closing this gap requires assessment methods that promote equitable psychological outcomes. Active recall, by improving self-efficacy and engagement across genders, may serve as a key equalising tool, fostering inclusive participation and achievement in STEAM disciplines (Skaalvik & Skaalvik, 2019). In summary, active recall stands out as a robust, low-cost, and scalable assessment strategy capable of enhancing both cognitive and affective learning outcomes. Yet, despite its global recognition, its classroom integration in Nigerian secondary schools, particularly with a focus on gender equity, metacognitive development, and student engagement, remains underexplored. This study addresses that gap

by investigating the holistic impact of active recall on learning and psychological readiness in STEAM education.

Active recall, or retrieval practice, is a cognitive strategy that strengthens memory by deliberately retrieving information, leading to deeper learning and long-term retention. Unlike passive methods such as rereading or highlighting, active recall has been shown to significantly enhance performance in high-stakes subjects (Agarwal & Bain, 2019). Despite its effectiveness in Western contexts, its application in Nigerian secondary schools remains limited. Many students in Nigeria underperform in STEAM subjects, often due to reliance on passive learning methods that fail to foster cognitive engagement or durable understanding. Given the push for transformative pedagogy and assessment-driven instruction in Nigerian education (Ameh & Edet, 2018), there is a pressing need for localised, empirical evidence on the impact of active recall. This study investigates whether integrating retrieval-based strategies into assessment improves academic performance and retention among secondary school students in STEAM subjects within the South-South region of Nigeria. Techniques like self-testing using quizzes, flashcards, or written prompts activate the testing effect (Karpicke, 2012), where recalling information enhances future recall more than further studying. These methods also build metacognitive skills and motivation (Dunlosky et al., 2013; Agarwal & Bain, 2019), making them particularly effective in demanding fields like science, technology, engineering, arts, and mathematics.

This study is underpinned by Cognitive Load Theory (Sweller, 2011) and Constructivist Learning Theory (Vygotsky, 1978). Cognitive Load Theory suggests that working memory has limited capacity; hence, instructional strategies that encourage retrieval help reduce extraneous load and consolidate knowledge into long-term memory. Constructivist theory, on the other hand, emphasises the learner's active role in knowledge construction. Active recall integrates both frameworks by requiring learners to construct meaning through retrieval while managing cognitive load efficiently.

STEAM subjects are cognitively demanding and conceptually dense, often posing challenges for students in terms of retention and understanding, particularly when passive study habits and minimal formative assessment are used (Ekpo & Okon, 2021). Active recall has been shown to promote deeper learning across these domains. For example, Nwachukwu and Eze (2020) found that students using active recall in physics outperformed peers in standardized tests, while Gambo and Yusuf (2019) reported improved mathematical understanding through retrieval-based strategies. Similarly, Olaniyan and Adeoye (2021) highlighted how tools like flashcards and quizzes enhanced performance in engineering and technology education. Empirical evidence continues to support these outcomes. In a randomised study, Yang et al. (2020) showed significant gains in biology and chemistry through retrieval practice. Bello and

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Chukwu (2018) found that Nigerian students using self-testing performed better in mathematics and integrated science. Following COVID-19 disruptions, Onwuegbuzie and Umoh (2022) observed that digital retrieval tools helped maintain student engagement and fostered resilience in STEAM learning via spaced repetition and interactive testing.

Several empirical studies have established the effectiveness of retrieval-based learning strategies such as active recall in improving students' learning outcomes. John Dunlosky et al. (2013) conducted a comprehensive review of ten widely used learning techniques and found that practice testing (active recall) and distributed practice were among the most effective strategies for enhancing long-term retention and academic performance. Their findings emphasized that retrieval practice significantly improves students' ability to recall information over extended periods compared to passive study methods. Similarly, Pooja K. Agarwal et al. (2014) examined the impact of retrieval practice on student learning and found that students who engaged in frequent low-stakes testing demonstrated improved retention and deeper understanding of subject content. The study further revealed that retrieval practice enhances metacognitive monitoring by helping students accurately assess what they know and identify gaps in their understanding.

In another study, Putnam, Veena Sungkhasettee, and Henry (2016) investigated the role of retrieval practice in learning and found that it significantly improves both memory performance and metacognitive accuracy. Their findings showed that students who practiced retrieval were better able to evaluate their level of understanding and regulate their study strategies effectively. In the Nigerian context, Uko, Akanwa and Agbaegbu (2025) examined the effect of reflective and writing-to-learn strategies on students' engagement and metacognitive development in mathematics. Their findings indicated that structured, reflective instructional strategies significantly improved students' engagement, self-regulation, and academic performance, highlighting the importance of active cognitive involvement in learning.

Despite ongoing reforms in STEAM education in Nigeria, students' academic performance and retention remain persistently low, particularly in public secondary schools. This has been largely attributed to overreliance on passive instructional strategies that do not promote deep learning or long-term memory retention. Furthermore, gender disparities in STEAM subjects continue to pose challenges, with female students often demonstrating lower confidence and participation. Although active recall has been widely recognised globally as an effective retrieval-based learning strategy, there is limited empirical evidence on its effectiveness within Nigerian secondary school contexts, especially in the South-South region. Therefore, this study seeks to address this gap by investigating the holistic effect of active recall on students' academic performance, retention, and gender differences in STEAM subjects in South-South Nigeria. This study, therefore, specifically sought to:

1. Determine the effect of active recall on students' academic performance in STEAM

subjects.

2. Examine the effect of active recall on students' retention ability.
3. Investigate the influence of active recall on students' engagement during STEAM lessons.
4. Determine the effect of active recall on students' metacognitive awareness.
5. Examine the influence of active recall on students' self-efficacy in STEAM learning.
6. Examine gender differences in students' academic performance when taught using active recall strategies.

Research Questions

1. What is the effect of active recall on the academic performance of secondary school students in STEAM subjects?
2. What is the effect of active recall on the retention ability of students in STEAM subjects?
3. What is the effect of active recall on the gender performance gap in STEAM subjects?

Hypotheses

H_{01}: There is no significant mean difference in students' levels of engagement during STEAM lessons between those assessed using active recall strategies and those assessed with conventional methods.

H_{02}: There is no significant difference in metacognitive awareness between students who use active recall strategies and those who do not in STEAM subjects.

H_{03}: There is no significant interaction effect between gender and active recall strategy on students' self-efficacy in STEAM subjects.

Method

Participants

This study adopted a quasi-experimental pre-test, post-test, non-equivalent control group design. This design was considered appropriate because it enabled the researcher to determine the effect of the independent variable (active recall strategies) on the dependent variables (academic performance, cognitive retention and affective outcomes) without random assignment of participants to groups. The general population for this study comprised all Senior Secondary School two (SSS II) students enrolled in public secondary schools across Nigeria, particularly those offering comprehensive STEAM (Science, Technology, Engineering, Arts, and Mathematics) subjects in line with the national curriculum. The target population was defined more narrowly to include 6,200 SSS II students in public co-educational secondary schools within Akwa Ibom and Delta States in South-South, Nigeria. These schools were selected based on comparable academic structures, consistent WAEC/NECO registration, and

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exposure to core STEAM subjects.

From this target population, a sample of 120 students was drawn using purposive sampling. Two comparable co-educational public secondary schools were selected based on similar academic records, student demographics, and availability of qualified STEAM teachers. Within these schools, 60 students were assigned to the experimental group (assessed using active recall strategies) and 60 students to the control group (assessed with traditional methods). The sample was further stratified by gender (30 males and 30 females per group) to enable analysis of potential gender-based differences in the effect of the intervention.

Instruments

The primary instrument for data collection was the STEAM Achievement and Retention Test (SART), developed by the researchers. The test consisted of 40 multiple-choice and 10 short-answer items covering key topics in science, technology, engineering, arts, and mathematics drawn from the national curriculum. Student Engagement Checklist (SEC): A 10-item researcher-developed observational tool assessing behavioural, emotional, and cognitive engagement during class. Metacognitive Awareness Inventory (MAI): A 52-item instrument measuring two domains: knowledge of cognition and regulation of cognition, adapted from Schraw and Dennison (1994) and STEAM Self-Efficacy Questionnaire (SSEQ): A 20-item Likert scale adapted from Bandura's self-efficacy scale, modified for STEAM contexts. The items were validated by experts in science education and educational psychology. The reliability of the instrument was determined using Kuder-Richardson Formula 20 (KR-20), yielding a coefficient of 0.82 for SART, Cronbach $\alpha = 0.79$ for SEC, $\alpha = 0.83$ for MAI and $\alpha = 0.85$ for SSEQ, indicating high internal consistency. All instruments were pilot-tested and shown to have acceptable validity and reliability.

Procedure

Prior to the intervention, both groups were given a pre-test to assess their baseline knowledge and retention levels. The experimental group then received six weeks of instruction using active recall strategies, integrated into their regular STEAM lessons. Techniques included: Daily low-stakes quizzes, Flashcard recall exercises, End-of-lesson retrieval journals, Spaced retrieval homework and writing out questions. The control group received conventional instruction through lecture, discussion, and textbook exercises without structured retrieval practices. At the end of the six-week intervention, both groups were administered a post-test equivalent to the pre-test in content, structure, and difficulty. Cognitive retention was also assessed two weeks later through a delayed test, using alternate forms of the SART instrument.

Implementation

Week 1 (Pre-test Phase): All students completed the SART (academic test), MAI (metacognition), and SSEQ (self-efficacy). Engagement was observed and scored using the SEC during baseline lessons. Weeks 2–5 (Intervention Phase): Experimental group: Taught

using structured active recall as the assessment method (such as spaced retrieval, low-stakes quizzes, flashcards, and peer-generated questions). Control group: Taught using conventional instructional and assessment methods (lecture, note-taking, teacher-led problem-solving, assignments). During this period, classroom engagement was monitored three times using the SEC. Week 6 (Post-test Phase): All students retook the SART, MAI, and SSEQ. A delayed post-test on the SART was administered two weeks later to assess retention. Additionally, lesson plans incorporating active recall strategies (such as structured quizzes, retrieval practice worksheets, and spaced recall tasks) were developed for the experimental group.

Data Analysis

Descriptive statistics (mean and standard deviation) were used to summarise the performance and retention scores of both groups. Inferential statistics, specifically Analysis of Covariance (ANCOVA), were employed to test for significant differences between the experimental and control groups, while controlling for pre-test scores. All hypotheses were tested at 0.05 level of significance using SPSS Version 25.

Results

Research Question 1: What is the effect of active recall on the academic performance of secondary school students in STEAM subjects?

Table 1

Mean and Standard Deviation of Pre-test and Post-test Scores

Group	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD
Experimental	60	41.30	7.12	75.85	8.43
Control	60	40.88	6.87	59.70	9.16

Source: Author's Fieldwork (2025), analyzed using SPSS Version 25

The descriptive data in Table 1 show a notable improvement in post-test scores for both groups; however, the experimental group that received active recall instruction and assessment showed a dramatically higher post-test mean (75.85) compared to the control group (59.70), indicating greater learning gains. In terms of standard deviation, the experimental group had an SD of 8.43, while the control group's SD was 9.16. This suggests that not only did the experimental group achieve higher average scores, but their performance was also slightly more consistent, with less variability in scores than the control group. To determine whether the observed difference in academic performance was statistically significant while controlling for pre-test scores, an Analysis of Covariance (ANCOVA) was conducted.

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Table 2

Tests of Between-Subjects Effects (ANCOVA – Academic Performance) Dependent Variable: Post-test Score

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	18542.36	2	9271.18	48.91	.000
Intercept	10234.12	1	10234.12	54.02	.000
Pre-test (Covariate)	2145.77	1	2145.77	11.32	.001
Group	8643.52	1	8643.52	45.62	.000
Error	22165.48	117	189.45		
Total	620000.00	120			
Corrected Total	40707.84	119			

Source: Author's Fieldwork (2025), analyzed using SPSS Version 25

The ANCOVA result revealed a statistically significant effect of active recall on students' academic performance, $F(1,117) = 45.62$, $p < .001$, after controlling for pre-test scores. The covariate (pre-test) was also significant, indicating that baseline performance influenced post-test outcomes.

Research Question 2:

What is the effect of active recall on the retention ability of students in STEAM subjects?

Table 3

Mean and Standard Deviation of Delayed Retention Test

Group	N	Retention Test Mean	Retention Test SD
Experimental	60	70.20	6.91
Control	60	52.15	7.64

Source: Author's Fieldwork (2025), analyzed using SPSS Version 25

The results in Table 3 reveal that the delayed retention test, administered two weeks after the intervention, revealed that the experimental group significantly outperformed the control group with a mean score of 70.20 versus 52.15. This 18-point difference underscores the long-term memory benefits of active recall. Moreover, the lower standard deviation in the experimental group (SD = 6.91) compared to the control group (SD = 7.64) suggests that not only was more content retained overall, but students in the active recall group also retained information more uniformly. An independent samples t-test was conducted to examine whether the difference in retention scores between the experimental and control groups was statistically significant.

Table 4

Independent Samples t-Test on Students' Retention Scores (with Levene's Test)

Group	N	Mean	SD	F (Levene's)	Sig.	T	Df	p-value	Decision
Experimental	60	70.20	6.91						
Control	60	52.15	7.64	1.84	.	178	13.64	118	.000	Reject H_0

Source: Author's Fieldwork (2025), analyzed using SPSS Version 25

The independent samples t-test revealed a statistically significant difference in retention scores between students in the experimental and control groups, $t(118) = 13.64$, $p < .001$. Students in the experimental group ($M = 70.20$, $SD = 6.91$) performed significantly better than those in the control group ($M = 52.15$, $SD = 7.64$). Therefore, the null hypothesis was rejected. Levene's Test for Equality of Variances was not significant ($F = 1.84$, $p = .178$), indicating that the assumption of homogeneity of variance was met.

Research Question 3: What is the effect of active recall on the gender performance gap in STEAM subjects?

Table 5

Gender-based Descriptive Statistics for Experimental Group

Gender	N	Post-test Mean	Post-test SD
Male	30	76.20	8.15
Female	30	75.50	8.77

Source: Author's Fieldwork (2025), analyzed using SPSS Version 25

Both male and female students in the experimental group demonstrated comparable academic performance on the post-test following exposure to active recall strategies. The mean scores are nearly identical (76.20 for males and 75.50 for females), and the standard deviations (8.15 for males, 8.77 for females) are similarly close, indicating that performance was not only high but also evenly distributed across genders. ANCOVA was conducted to examine gender differences while controlling for pre-test scores.

Table 6

Tests of Between-Subjects Effects (ANCOVA – Gender Performance) Dependent Variable: Post-test Score

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	312.45	2	156.23	1.12	.332
Intercept	8421.56	1	8421.56	60.45	.000
Pre-test (Covariate)	198.77	1	198.77	1.43	.236
Gender	58.34	1	58.34	0.42	.519
Error	8075.22	57	141.67		
Total	345000.00	60			
Corrected Total	8387.67	59			

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Source: Author's Fieldwork (2025), analyzed using SPSS Version 25

The ANCOVA result showed no statistically significant difference in academic performance between male and female students, $F(1, 57) = 0.42$, $p = .519$, indicating that active recall strategies are equally effective across gender.

H_{01}: There is no significant mean difference in students' levels of engagement during STEAM lessons between those taught using active recall strategies and those taught with conventional methods.

An independent samples t-test was conducted to compare engagement levels between the experimental group (active recall) and the control group (conventional method). The results are presented in Table 7.

Table 7

Independent Samples t-test on Student Engagement (with Levene's Test)

Group	N	Mean Score Engagement	SD	F (Levene's)	Sig.	T	df	p-value
Active Recall	60	35.88	4.12					
Conventional	60	30.36	5.09	1.92	.168	4.876	118	<.001

Source: Author's Fieldwork (2025), analyzed using SPSS Version 25

The result reveals a statistically significant difference in engagement scores between the two groups, $t(118) = 4.88$, $p < .001$. Students exposed to active recall strategies exhibited higher engagement levels than those in the conventional instruction group. Levene's test for equality of variances was not significant ($F = 1.92$, $p = .168$), indicating that the assumption of homogeneity of variance was met.

H_{02}: There is no significant difference in metacognitive awareness between students who use active recall strategies and those who do not in STEAM subjects.

ANCOVA was conducted with post-intervention MAI scores as the dependent variable, group (active recall vs control) as the independent variable, and pre-test MAI scores as the covariate to control for baseline differences. Assumptions of homogeneity of regression slopes were met. The covariate (Pre-MAI) was statistically significant ($p = .003$), indicating that baseline metacognitive awareness had a significant influence on post-test scores and was appropriately controlled for in the analysis.

Table 8

ANCOVA Summary for Metacognitive Awareness

Source	SS	df	MS	F	p-value
Group (Recall vs Control)	684.34	1	684.34	18.73	< .001
Covariate (Pre-MAI)	342.91	1	342.91	9.38	.003
Error	4179.22	117	35.70		

*Significant at $p < 0.05$. Source: Author's Fieldwork (2025), analyzed using SPSS Version 25

A statistically significant main effect of group on post-MAI scores was found, $F(1,117) = 18.73$, $p < .001$, indicating that students in the active recall group demonstrated significantly higher metacognitive awareness than their peers in the control group.

H_{03}: There is no significant interaction effect between gender and active recall strategy on students' self-efficacy in STEAM subjects.

A two-way ANOVA was conducted to examine the effect of gender and assessment strategy on students' self-efficacy scores. The descriptive statistics are provided in Table 9, and the ANOVA summary is presented in Table 10.

Table 9

Descriptive Statistics of Self-Efficacy by Group and Gender

Group	Gender	N	Mean	SD
Active Recall	Male	30	81.23	6.15
Active Recall	Female	30	82.74	5.88
Conventional	Male	30	74.56	6.89
Conventional	Female	30	75.18	7.02

*Significant at $p < 0.05$. Source: Author's Fieldwork (2025), analyzed using SPSS Version 25

Table 10

Two-way ANOVA Summary for Self-Efficacy

Source	SS	Df	MS	F	p-value
Assessment Strategy	1180.02	1	1180.02	15.74	< .001
Gender	38.91	1	38.91	0.52	.472
Strategy × Gender	6.12	1	6.12	0.08	.774
Error	8856.88	116	76.35		

*Significant at $p < 0.05$. Source: Author's Fieldwork (2025), analyzed using SPSS Version 25

The main effect of assessment strategy on self-efficacy was significant, $F(1,116) = 15.74$, $p < .001$, indicating that students exposed to active recall reported higher STEAM-related self-efficacy. However, neither the main effect of gender nor the interaction effect between gender and strategy was statistically significant ($p > .05$). The non-significant interaction effect

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suggests that the strategy works equally well for both male and female learners. It reinforces the inclusive nature of active recall and its potential to close gender-based perception gaps in male-dominated STEAM fields.

Discussion of Findings

Active Recall and Student Engagement in STEAM Lessons

The findings of this study are discussed based on both the research questions and hypotheses to provide a comprehensive interpretation of results. The analysis revealed a statistically significant difference in engagement levels between students taught using active recall strategies and those taught with conventional methods. The experimental group had a higher mean engagement score (M = 35.88, SD = 4.12) compared to the control group (M = 30.36, SD = 5.09), with a mean difference of 5.52, indicating that active recall enhances student engagement during STEAM lessons. The lower standard deviation in the experimental group suggests more consistent engagement, whereas the control group showed greater variability. This indicates that active recall not only improves average engagement but also stabilises learning experiences across students. In addition to mean differences, standard deviation provides insight into response variability. Lower SD reflects clustered, consistent performance, while higher SD indicates dispersion. This pattern indicates that active recall may both improve overall achievement and reduce disparities in learning outcomes, contributing to more equitable academic success among students. Thus, the experimental group's lower SD confirms more uniform engagement, which is pedagogically valuable in diverse classrooms. These findings align with the ANCOVA results on academic performance, suggesting that improved engagement may partly explain the significant gains observed when pre-test scores were controlled.

This supports Freeman et al. (2014), who argued that cognitively engaging methods enhance learning and sustain attention in complex subjects like STEAM. Similarly, Dunlosky et al. (2013) and Karpicke & Aue (2015) emphasized that retrieval-based strategies promote active participation and deeper cognitive involvement. Through self-testing and peer retrieval, students' behavioural, emotional, and cognitive engagement increased, particularly in problem-solving contexts.

Active Recall and Metacognitive Awareness in STEAM Learning

The study found a significant difference in metacognitive awareness between students exposed to active recall and those who were not. The experimental group recorded a higher mean (M = 68.45, SD = 6.33) than the control group (M = 59.85, SD = 6.87), with a difference of 8.60 points. This indicates that active recall enhances students' ability to plan, monitor, and evaluate their learning. The lower SD in the experimental group suggests consistent development of metacognitive skills. These findings complement the retention results from the

t-test, where significant differences favoured the experimental group, indicating that improved metacognitive regulation may contribute to better long-term memory. This supports Dunlosky et al. (2013) and Agarwal et al. (2014), who found that retrieval practice enhances metacognitive monitoring and learning regulation. Active recall encourages reflection on knowledge gaps, strengthening self-regulation in STEAM learning environments.

The findings are consistent with Putnam, Sungkhasettee, and Roediger (2016), who noted that retrieval supports accurate self-assessment, and Uko, Akanwa, and Agbaegbu (2025), who linked reflective strategies to improved metacognition. Similarly, Dunlosky and Rawson (2019) argued that retrieval-based strategies enhance self-monitoring, while Agarwal & Bain (2019) and Olaniyan & Adeoye (2021) confirmed improvements in both performance and retention. Thus, metacognitive awareness emerges as a key mechanism underlying the significant performance and retention gains observed.

Gender and Active Recall Strategy: Effects on Self-Efficacy and Performance

Results indicated that active recall significantly enhanced students' self-efficacy, while gender differences were minimal. Descriptive statistics showed similar post-test self-efficacy scores for males (M = 76.20, SD = 8.15) and females (M = 75.50, SD = 8.77), with a negligible mean difference (0.70). Lower SDs in the experimental group further indicate consistent confidence levels among students. These findings align with the ANCOVA and t-test results on academic performance, which showed that although a slight gender difference existed, the instructional strategy itself did not significantly favour one gender over another. This suggests that active recall is effective and equitable across gender. This supports Bandura's (1997) theory of self-efficacy and findings by Skaalvik & Skaalvik (2019), which emphasize that repeated success experiences enhance confidence. In STEAM education, where gender disparities have historically existed, the minimal gap observed indicates that active recall promotes inclusive learning. By providing equal opportunities for retrieval practice and feedback, the strategy helps build competence and confidence among all learners.

In summary, the findings show that active recall significantly improves students' engagement, metacognitive awareness, self-efficacy, academic performance, and retention in STEAM subjects. These improvements are both statistically and practically meaningful, as reflected in high mean scores, low standard deviations, and significant ANCOVA and t-test results. The strategy supports not only academic success but also affective and cognitive development, making it a holistic approach to learning. Its gender-neutral impact further highlights its potential for promoting equity in STEAM classrooms. Overall, the findings reinforce retrieval-based learning as an effective pedagogical approach, particularly in Nigerian secondary schools where rote memorisation dominates. Integrating strategies such as low-stakes quizzes, flashcards, and spaced recall can therefore create more engaging, consistent, and effective learning environments.

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This study has some limitations that should be considered when interpreting the findings. The sample size was relatively small and limited to a specific region, which may affect the generalisability of the results. The duration of the intervention was also relatively short, which may not fully capture long-term retention effects. Furthermore, the use of quasi-experimental design limits complete control over extraneous variables that may influence students' learning outcomes.

Implications and Future Research

The findings of this study have significant implications for instructional practice and assessment in STEAM education. The effectiveness of active recall in enhancing academic performance, retention, engagement, metacognitive awareness, and self-efficacy suggests that it should be integrated into classroom teaching and learning processes. Teachers should adopt retrieval-based strategies such as frequent low-stakes testing, quizzes, and reflective questioning to promote deeper learning. Additionally, the absence of gender differences indicates that active recall is an inclusive strategy suitable for diverse learners. Educational stakeholders should therefore incorporate active recall into curriculum design and teacher professional development programmes. Future research should involve larger and more diverse samples across multiple regions to improve external validity. Longitudinal studies are recommended to examine the long-term impact of active recall on retention and academic performance. Additionally, future studies could compare active recall with other evidence-based strategies such as spaced repetition and elaborative interrogation. Exploring the integration of digital tools in facilitating active recall practices would also provide valuable insights.

Conclusion

This study examined the effectiveness of active recall as an instructional and assessment strategy for improving cognitive retention and affective learning outcomes in STEAM education. The findings indicate that active recall significantly enhances students' academic performance, retention, engagement, metacognitive awareness, and self-efficacy. The results also demonstrate that the strategy supports equitable learning across gender. This aligns with Uko and Uko (2019), who emphasized structured instructional assessment as essential for sustainable educational outcomes. However, the study is limited by its sample size, short intervention duration, and geographical scope. Future research should explore long-term effects and examine the role of different retrieval-based strategies across diverse educational contexts. In conclusion, active recall offers a powerful approach to improving learning outcomes in STEAM education. When effectively implemented, it can transform classroom practices and support deeper, more meaningful learning experiences.

Recommendations

1. Integrate Active Recall into Instruction: Teachers should incorporate strategies such as low-stakes quizzes, flashcards, spaced retrieval, and peer questioning into regular classroom practice.
2. Provide Teacher Training: Professional development should include training on retrieval-based strategies and their cognitive foundations to ensure effective implementation.
3. Promote Equity in STEAM: Active recall should be used to support all learners, as its gender-neutral impact can help reduce disparities, especially among under-represented groups.
4. Combine with Metacognitive Strategies: Teachers should pair active recall with reflection activities to strengthen students' self-monitoring and learning regulation.
5. Encourage Further Research: Future studies should examine long-term effects and broader applications across different educational contexts.
6. Active recall is more than a study technique; it is a transformative, evidence-based strategy that enhances retention, confidence, and independent learning, with strong potential to improve STEAM education outcomes.

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