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Effect of Metacognitive Instructional Strategy on Chemistry Students' Academic Achievement and Retention

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ABSTRACT

The study, effect of Metacognitive Instructional Strategy (MIS) on Chemistry student academic achievement and retention in secondary schools in Orumba North Local Government Area, was conducted in response to the increasing declining interest in chemistry, lack of technological advancement, creativity and abstract nature of chemistry content among chemistry students. The study was guided by six research questions and six null hypotheses. Quasi-experimental research design, which involves comparing groups to determine the effect of an intervention, was adopted for the study. The population of the study was 234 senior secondary year two (SS2) students who offered Chemistry in Orumba North Local Government Area in Anambra State, Nigeria in the year 2024/2025. A sample size of 129 students was drawn from the population using simple random sampling (balloting with replacement). The instrument for data collection was Periodic Table Achievement Test (PTAT) validated by three experts, two from the department of science and one department of educational foundation, all from the faculty of education. The reliability of the instrument was established using Kuder-Richardson 20 for PTAT which yielded coefficient values of 0.82. Data generated was analyzed using Mean and standard deviation to answer the research questions, while ANCOVA was used to test the null hypotheses at 0.05 significant levels The findings of the study revealed that students taught with Metacognitive instructional strategy achieved higher mean scores in Chemistry concepts, than those taught with conventional lecture method. It also revealed that male students taught Chemistry using MIS had higher mean academic achievement scores than females. The study found a significant interaction effect between instructional strategy and gender on academic achievement and retention. The study recommended among others that Chemistry teachers should adopt Metacognitive instructional strategy in teaching Chemistry to enhance academic achievement and retention and apply gender-responsive strategy when using MIS to ensure male and female students are equally engaged during Chemistry instruction.

Keywords: Metacognitive Instructional Strategy, Conventional lecture method and Retention, Chemistry Students' Academic Achievement and Retention

INTRODUCTION

Chemistry is fundamental in elucidating the composition, structure, and transformation of matter at the molecular level. Its significance extends beyond theoretical comprehension to include industrial advancements in pharmaceuticals, agriculture, and energy systems. It seeks to understand the fundamental principles that govern the behavior of atoms and molecules. According to Nnoli (2021) Chemistry is a discipline with high standard of conduct which must be amplified by teachers and researchers in ways that students cannot fail to observe and adopt. Chemistry presents a particularly critical case. Often termed the "central science," it provides the foundational principles that help in explaining the composition, structure, properties, and transformations of matter at a molecular level (Nnoli and Samuel; 2023). Its applications are the bedrock of critical industries, from Pharmaceutical and Agriculture to Energy and Materials Science, making it indispensable for economic diversification and sustainable development (Olatoye, Aderogba, and Aanu 2019). Chemistry is the scientific discipline that studies the properties, composition, structures and behavior of matter. It seeks to understand the fundamental principles that govern the behavior of atoms and molecules.

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The power of Chemistry is what creates a whole and enabling infrastructure that delivers, Food, Medicine and Materials which are the hall mark of modern life.

Metacognitive Instructional Strategy offers a different approach that can address these problems. The metacognitive instructional technique highlights learners' capacity to manage their cognitive processes via planning, monitoring, and evaluation. This method transitions learning from passive absorption to active cognitive involvement (Dunlosky, Rawson and Nathan, 2023). When students use Metacognitive strategy, they ask themselves questions like "Do I understand this concept?", "What should I do if I am confused?", and "How can I check if my answer is correct?" These questions help students take charge of their learning instead of depending only on the teacher (Muteti, Jacob and Mutambuki, 2023). Combination of memorization demands (symbols, atomic numbers), pattern recognition skills (trends in properties), and conceptual understanding (linking position to behavior) is essential. Lack of focused studies on applying Metacognitive Strategy to overcome these specific learning hurdles represents a clear gap in the literature.

Academic achievement signifies students' proficiency in subject matter, usually evidenced by their capacity to apply concepts, resolve issues, and excel in both formative and summative evaluations. In Chemistry education, academic achievement shows whether students can understand chemical concepts, solve Chemistry problems, and apply chemical knowledge to real situations. Ikwuka and Adigwe (2021) argue that academic achievement, often measured through examinations or continuous assessments, is a product of learning. It is the students' results which are assessed by the Scores, Tests and Examinations. According to Muteti, Jacob and Mutambuki(2023) academic achievement refers to the overall accomplishment of students' which is evident in their scores in standardized examination. Therefore, students' low academic achievement in Chemistry does not just affect their grades; it is a serious barrier that limits their future career options in fields that are essential for Nigeria's development.

Retention denotes the degree to which previously acquired knowledge can be maintained throughout time and utilized in future learning scenarios. According to Nnoli and Samuel (2023), many students forget Chemistry concepts shortly after examinations, suggesting that conventional lecture method do not lead to lasting understanding. This is a serious problem because Chemistry concepts build on each other, students need to remember basic concepts to understand more advanced ones. The reason of this problem is multifaceted, but a substantial body of research points to the predominance of teacher- centered, expository instructional methods as a major contributing factor (Onwukwe, 2021). Such methods, characterized by rote memorization and passive knowledge reception, often fail to actively engage students in the cognitive processes necessary for deep and conceptual understanding. This leads to superficial learning, where students can recall facts for examinations but cannot apply concepts to novel problems, resulting in poor long - term retention. The main cause of poor achievement Andrew low retention in Chemistry has been linked to how the subject is taught.

Traditional lecture-based teaching often renders students as passive consumers of knowledge, restricting opportunities for active participation and advanced cognitive processes (Ibe, 2025). In these methods, students do not actively participate in their learning process. They depend completely on the teacher to give them information, which they try to memorize without really understanding (Agu and Iyamu, 2020). This approach does not help students to develop the thinking skills they need to solve in Chemistry problems. When students learn this way, they quickly forget what they were taught and cannot apply the knowledge to new situations, which hinders their ability to tackle complex Chemistry problems effectively and limits their overall academic success. By applying innovative approaches as remedies to teaching and learning barriers, students' achievement may be improved and the retention of learned material maybe enhanced as the global educational

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landscape has witnessed a paradigm shift from Conventional pedagogy towards constructivist approaches that empower learners to take control of their own learning processes.

Gender is a social, cultural and psychological attributes, behaviours and roles that a society considers appropriate for men, women and other gender identities. Gender according to Okeke (2018), refers to those characteristics of male and female which are biologically determined such as possession of penis by males and vagina by females in a society. Christler and Lamar (2018) states that gender is individuals social identity and personality or behavioural tendencies. (E.g., masculine, feminine, androgynous, transgender).

Despite the substantial research on metacognitive instructional strategies in science education, there is a paucity of empirical studies that specifically investigate how these strategies concurrently affect academic achievement and retention in chemistry learning, especially regarding conceptually challenging subjects like the Periodic Table.

Furthermore, prior research has predominantly concentrated on general learning results, neglecting to adequately investigate the role of metacognitive processes in information retention over time via mechanisms such as encoding, monitoring, and retrieval. The relationship between metacognitive teaching tactics and gender in influencing success and retention results is still unclear.

This study examines the influence of metacognitive teaching strategies on students' academic achievement, their contribution to long-term retention, and their varying effects based on gender.

1. Statement of the Problem

The ideal situation in Nigerian secondary schools was for chemistry to be a subject that students understood and enjoyed. Students were able to grasp important concepts, achieve high scores in their exams, and most importantly, remember this knowledge long after the lessons were over. Effective teaching methods actively involved both male and female students in the learning process, helping them to think critically and solve problems on their own. This led to strong academic achievement and excellent retention of knowledge, preparing a new generation of scientists and innovators for the nation.

However, secondary schools in Orumba North Local Government Area and across Nigeria present a different reality. Many researchers had argued that the main cause of this problem was the continued use of conventional lecture methods, which made students passive. While this was true, most of the solutions suggested had been general. There had been a major oversight in exploring the specific role that targeted metacognitive instructional strategy could play in improving both achievement and retention, especially for difficult topics like the Periodic Table, which often challenges students' understanding due to its complexity and the abstract nature of its concepts.

Given that the Periodic Table required students to understand abstract concepts about atomic structure, recognize patterns and trends in element properties, memorize symbols and atomic numbers, and make connections between an element's position and its chemical behavior—all of which demanded strong metacognitive skills to plan problem-solving steps, monitor pattern recognition skills, and evaluate whether answers made sense—this study became necessary. Therefore, this study was necessary to end this argument by directly investigating the effect of a metacognitive instructional strategy on student academic achievement and retention in chemistry, while also determining its impact across gender groups.

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2. Purpose of the Study

The purpose of this study was to investigate the effects of a Metacognitive Instructional Strategy on the academic achievement and retention of chemistry students in secondary schools. Specifically, the study sought to determine the:

a. Mean academic achievement scores of students taught Chemistry using the metacognitive instructional strategy and those taught using the conventional lecture method among secondary school students in Orumba North LGA.
b. Mean academic achievement scores of male and female students taught Chemistry using the metacognitive instructional strategy among secondary school students in Orumba North LGA.
c. Mean retention scores of students taught Chemistry using the metacognitive instructional strategy and those taught using the conventional lecture method among secondary school students in Orumba North LGA.
d. Mean retention scores of male and female students taught Chemistry using the metacognitive instructional strategy among secondary school students in Orumba North LGA.

3. Research Questions

The following research questions guided the study:

a. What is the difference in the mean academic achievement scores of students taught Chemistry with the metacognitive instructional strategy and those taught with the conventional lecture method?
b. What is the difference in the mean academic achievement scores of male and female students taught Chemistry using the metacognitive instructional strategy?
c. What is the difference in the mean retention scores of students taught Chemistry with the metacognitive instructional strategy and those taught with the conventional lecture method?
d. What is the difference in the mean retention scores of male and female students taught Chemistry using the metacognitive instructional strategy?

4. Hypotheses

The following null hypotheses were tested at a 0.05 level of significance:

a. There is no significant difference in the mean academic achievement scores of students taught Chemistry with the metacognitive instructional strategy and those taught with the lecture method.
b. There is no significant difference in the mean academic achievement scores of male and female students taught Chemistry using the metacognitive instructional strategy.
c. There is no significant difference in the mean retention scores of students taught Chemistry with the metacognitive instructional strategy and those taught with the lecture method.
d. There is no significant difference in the mean retention scores of male and female students taught Chemistry using the metacognitive instructional strategy.

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METHODS

The study adopted a pretest-posttest non-equivalent control group quasi-experimental design, specifically the pretest-posttest non-equivalent control group design. The area of the study was Orumba North Local Government Area.

The population and sample of the study comprised 237 participants. The participants were selected from two out of 13 public secondary schools in the area using simple random sampling (balloting with replacement).

The instrument for data collection was the Periodic Table Achievement Test. The instrument was structured into two parts. The instrument's face validation was done by three experts and was subjected to reliability testing. The reliability coefficient of the instrument was found to be 0.82, which confirmed its reliability. The experimental procedure for this study spanned a total period of seven weeks, including One week for pretest administration, Three weeks for the instructional intervention, One week for immediate posttest administration, One week of no intervention to allow for the retention interval and One week for delayed posttest administration . Prior to the administration of treatment, a pretest was administered to determine students' prior knowledge related to the Periodic Table concept. After the posttest, questions were reshuffled for the retention test to assess how well students retained their knowledge of the Periodic Table concept after the treatment. Mean was used to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses at an alpha level of 0.05.

RESULT AND DISCUSSION

Difference in Mean Academic Achievement between Metacognitive Instructional Strategy and Lecture Method

Table1: Mean and Standard Deviation of Students' Achievement Scores by Instructional Strategy

	Pre-Test			Post-Test			
Group	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**Mean Gain**
Experimental(MIS)	74	24.35	4.12	74	38.68	5.23	14.33
Control(Lecture)	55	24.11	4.28	55	31.45	5.87	7.34

Table 1 shows the mean achievement scores of students taught Chemistry using the metacognitive instructional strategy and those taught using the conventional lecture method. The table reveals that at pretest, students in the metacognitive strategy group had a mean score of 24.35 with a standard deviation of 4.12, while students in the conventional lecture method group had a mean score of 24.11 with a standard deviation of 4.28, indicating that both groups were approximately equivalent at baseline with a negligible difference of 0.24.

Table2: Analysis of Covariance (ANCOVA) of Students' Achievement Scores by Instructional Strategy

Source of Variation	**Sum of Squares**	**Df**	**Mean Squares**	**F-cal**	**Sig. of F.**
Covariate(Pretest)	1456.32	1	1456.32	48.67	0.000
Instructional Strategy	1834.65	1	1834.65	61.32	0.000
Error	3772.18	126	29.94		
Total	7063.06	128			

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Table 2 presents the Analysis of Covariance results for students' achievement scores by instructional strategy, with pretest scores as the covariate. The table shows that the covariate, pretest scores, had a significant effect with F(1,126) = 48.67 and p-value = 0.000, which is less than 0.05, indicating that pretest scores significantly influenced posttest achievement and justifying its inclusion as a covariate.

More importantly, the main effect of instructional strategy yielded F(1,126) = 61.32 with a p-value of 0.000, which is less than the 0.05 alpha level. Since the calculated p-value is less than 0.05, the null hypothesis is rejected. This means there is a statistically significant difference in the mean academic achievement scores of students taught Chemistry using the metacognitive instructional strategy and those taught using the conventional lecture method.

Gender Difference in Academic Achievement under Metacognitive Instructional Strategy

Table 3: Mean and Standard Deviation of Achievement Scores of Male and Female Students in the Metacognitive Strategy Group

		Pre-Test			Post-Test		
Group	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**Mean Gain**
Male	36	24.58	4.05	36	40.22	4.89	15.64
Female	38	24.13	4.19	38	37.26	5.31	13.13

Table 3 presents the mean achievement scores of male and female students taught Chemistry using the metacognitive instructional strategy. The table shows that at pretest, male students had a mean score of 24.58 with a standard deviation of 4.05, while female students had a mean score of 24.13 with a standard deviation of 4.19, showing both groups started with comparable baseline scores with a difference of only 0.45.

At posttest, male students achieved a mean score of 40.22 with a standard deviation of 4.89, while female students achieved a mean score of 37.26 with a standard deviation of 5.31, representing a posttest mean difference of 2.96 in favor of male students.

Table 4: Analysis of Covariance (ANCOVA) of Achievement Scores of Male and Female Students in the Metacognitive Strategy Group

Source of Variation	**Sum of Squares**	**Df**	**Mean Squares**	**F-cal**	**Sig. of F.**
Covariate(Pretest)	724.58	1	724.58	29.87	0.000
Gender	163.42	1	163.42	6.74	0.012
Error	1723.16	71	24.27		
Total	2611.16	73			

Table 4 shows the Analysis of Covariance results comparing achievement scores of male and female students who were taught using the metacognitive instructional strategy, with pretest scores as the covariate. The covariate, pretest scores, had a significant effect with F(1,71) = 29.87 and p-value = 0.000, confirming that pretest achievement influenced posttest scores.

The main effect of gender yielded F(1,71) = 6.74 with a p-value of 0.012, which is less than the 0.05 significance level. Since the p-value is less than 0.05, the null hypothesis is rejected. This indicates that there is a statistically significant difference in the mean academic achievement scores of male and female students taught Chemistry using the metacognitive instructional strategy, with male students performing significantly better than female students.

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However, it is important to note that while this difference is statistically significant, the mean difference of 2.96 points suggests that the practical magnitude of this gender difference is relatively modest, and both genders benefited substantially from the metacognitive approach.

Difference in Mean Retention between Metacognitive Instructional Strategy and Lecture Method

Table 5: Mean and Standard Deviation of Students' Retention Scores by Instructional Strategy

	Post-Test			Delayed Post-Test			
Group	**N**	**Mean**	**SD**	**N**		**SD**	**Mean Loss**
Experimental (MIS)	74	38.68	5.23	74	37.14	5.48	-1.54
Control (Lecture)	55	31.45	5.87	55	27.82	6.13	-3.63

Table 5 presents the mean retention scores of students taught Chemistry using the metacognitive instructional strategy compared to those taught using the conventional lecture method. The table shows that at the immediate posttest, students in the metacognitive strategy group had a mean score of 38.68 with a standard deviation of 5.23, while students in the conventional lecture method group had a mean score of 31.45 with a standard deviation of 5.87.

At the delayed posttest administered four weeks later to measure retention, students in the metacognitive strategy group achieved a mean score of 37.14 with a standard deviation of 5.48, while those in the conventional lecture method group achieved a mean score of 27.82 with a standard deviation of 6.13, representing a delayed posttest mean difference of 9.32 in favor of the metacognitive strategy group.

Table 6: Analysis of Covariance (ANCOVA) of Students' Retention Scores by Instructional Strategy

Source of Variation	**Sum of Squares**	**Df**	**Mean Squares**	**F-cal**	**Sig. of F.**
Covariate (Posttest)	1823.74	1	1823.74	56.42	0.000
Instructional Strategy	2147.89	1	2147.89	66.45	0.000
Error	4073.52	126	32.33		
Total	8045.15	128			

Table 6 presents the Analysis of Covariance results for students' retention scores by instructional strategy, with immediate posttest scores as the covariate. The covariate, immediate posttest scores, had a significant effect with $F(1,126) = 56.42$ and p-value = 0.000, which is less than 0.05, indicating that immediate posttest achievement significantly predicted retention scores and validating its use as a covariate.

The main effect of instructional strategy yielded $F(1,126) = 66.45$ with a p-value of 0.000, which is less than the 0.05 alpha level. Since the calculated p-value is less than 0.05, the null hypothesis is rejected. This means there is a statistically significant difference in the mean retention scores of students taught Chemistry using the metacognitive instructional strategy and those taught using the conventional lecture method.

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Gender Difference in Retention under Metacognitive Instructional Strategy

Table 7: Mean and Standard Deviation of Retention Scores of Male and Female Students in the Metacognitive Strategy Group

		Post-Test			Delayed Post-Test		
Group	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**Mean Loss**
Male	36	40.22	4.89	36	38.94	5.12	-1.28
Female	38	37.26	5.31	38	35.50	5.63	-1.76

Table 7 shows the mean retention scores of male and female students taught Chemistry using the metacognitive instructional strategy. At the immediate posttest, male students had a mean score of 40.22 with a standard deviation of 4.89, while female students had a mean score of 37.26 with a standard deviation of 5.31.

At the delayed posttest administered four weeks later, male students achieved a mean score of 38.94 with a standard deviation of 5.12, while female students achieved a mean score of 35.50 with a standard deviation of 5.63, representing a delayed posttest mean difference of 3.44 in favor of male students.

The mean change scores indicate that male students experienced a decline of 1.28 points from posttest to delayed posttest, whereas female students experienced a slightly larger decline of 1.76 points. Despite this difference in retention loss, both male and female students demonstrated relatively strong retention of Periodic Table concepts when taught using the metacognitive instructional strategy, with the minimal decline suggesting that the metacognitive approach helped both genders retain most of what they learned.

The results indicate that while male students retained slightly more knowledge than female students, both genders benefited from the metacognitive strategy in terms of long-term retention compared to what would be expected with conventional instruction.

Table 8: Analysis of Covariance (ANCOVA) of Retention Scores of Male and Female Students in the Metacognitive Strategy Group

Source of Variation	**Sum of Squares**	**Df**	**Mean Squares**	**F-cal**	**Sig. of F.**
Covariate (Pretest)	892.36	1	892.36	34.18	0.000
Gender	178.94	1	178.94	6.85	0.011
Error	1853.42	71	26.10		
Total	2924.72	73			

Table 8 presents the Analysis of Covariance results comparing retention scores of male and female students who were taught using the metacognitive instructional strategy, with immediate posttest scores as the covariate. The covariate, immediate posttest scores, had a significant effect with $F(1,71) = 34.18$ and p-value = 0.000, confirming that immediate posttest achievement influenced retention scores.

The main effect of gender yielded $F(1,71) = 6.85$ with a p-value of 0.011, which is less than the 0.05 significance level. Since the p-value is less than 0.05, the null hypothesis is rejected. This indicates that there is a statistically significant difference in the mean retention scores of male and female students taught Chemistry using the metacognitive instructional strategy, with male students demonstrating significantly better retention than female students. The discussion is structured to interpret the findings beyond statistical significance by linking the observed results to underlying cognitive processes and existing theoretical perspectives.

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Effect of Metacognitive Instructional Strategy on Academic Achievement

The notable disparity in performance between the MIS and lecture groups signifies not only instructional differences but also variations in cognitive engagement throughout the learning process. The elevated mean gain in the MIS group (14.33) relative to the lecture group (7.34) indicates that students engaged with the topic actively rather than only being exposed to it.

Metacognitive cues undoubtedly facilitated students in regulating their cognition, assessing their comprehension, and modifying learning tactics in real time. This active regulation improves conceptual comprehension, which is essential in chemistry where abstract linkages must be assimilated. Consequently, the noted achievement benefits may be construed because of enhanced cognitive control rather than simply exposure to educational material.

The findings also agree with that of Kadıoğlu-Akbulut and Uzuntiryaki-Kondakçı (2021), who reported achievement improvements when Turkish students were taught Chemistry using metacognitive strategy, while Richards-Babbe et al. (2025) demonstrated that frequent metacognitive reporting in Chemistry courses significantly improved student success.

Gender Differences in Achievement within Metacognitive Strategy Group

These findings showed that among students taught with the metacognitive instructional strategy, male students achieved higher mean scores than female students, with this difference being statistically significant, leading to the rejection of the null hypothesis.

Although the results show a statistically significant advantage in favor of male students, the relatively tiny mean difference implies that the practical impact is restricted. Both male and female students derived significant advantages from the metacognitive approach, particularly in areas such as problem-solving skills and academic performance, which contributed to their overall learning outcomes.

This finding may be understood as a reflection of variations in self-regulation tendencies rather than innate aptitude. Male students in this environment may have engaged more confidently with self-directed metacognitive prompts, whereas female students might necessitate more formal scaffolding to effectively employ similar tactics, indicating that different instructional strategies may be required to support each gender's learning process. Consequently, the outcome should not be perceived as a constraint of the plan, but rather as a signal for the necessity of adaptive execution.

However, this finding contrasts with Agu (2020), who found no significant gender differences when students were taught organic chemistry using Predict-Explain-Observe-Explain and Vee Heuristic strategies. The different nature of the metacognitive strategy employed may explain this discrepancy. Agu's strategies were teacher-led, with the instructor actively guiding students through metacognitive processes as a collective activity, whereas the present study used a metacognitive strategy where students independently applied metacognitive prompts.

Similarly, Oyovwi and Iroriteraye-Adjekpovu (2021) reported no significant gender differences when students were taught science using group-based metacognitive activities.

Effect of Metacognitive Instructional Strategy on Retention

The results regarding retention offer compelling evidence of the cognitive benefits associated with metacognitive instructional strategies. The statistics indicate that students in the MIS group encountered a negligible reduction (mean loss = 1.54) in contrast to a much greater decline in the lecture group (mean loss = 3.63).

This disparity is not solely statistical but signifies a fundamental divergence in the processing and storage of knowledge. The comparatively steady retention noted in the MIS group indicates that pupils participated in more profound encoding processes during learning. By engaging in planning, monitoring, and assessment tasks, learners were more inclined to organize material coherently rather than memorize it superficially.

This supports the notion that metacognitive activity enhances both encoding and retrieval processes from a cognitive standpoint. Students who diligently assessed their comprehension were more adept at recognizing knowledge deficiencies and consolidating learning during the educational period. Consequently, the material was more accessible during the postponed post-test, signifying enhanced retrieval structures, which allowed students to perform better and demonstrate a deeper understanding of the content compared to their initial assessments.

The significant drop noted in the lecture group indicates dependence on superficial processing, wherein knowledge is momentarily held but not well integrated into long-term memory.

Gender Differences in Retention within Metacognitive Strategy Group

These findings indicated that while both male and female students in the metacognitive group retained their knowledge well with minimal decline, males experienced slightly less forgetting than females. This difference was statistically significant, leading to the rejection of the null hypothesis.

The empirical literature on gender differences in retention when using metacognitive strategies yields mixed findings. Ibe (2025), Oyovwi and Iroriteraye, and Dewi, Martini, and Mujakir (2025) all reported that metacognitive or cooperative strategies benefited both genders' retention with no significant gender differences. This evidence makes the present study's finding of significant gender differences divergent from some previous Nigerian studies.

Several factors may explain this discrepancy. The present study focused specifically on chemistry, suggesting that the nature of the metacognitive strategy may interact with gender in ways that affect retention differently. Additionally, the Periodic Table as content may present unique challenges, as learning it requires both memorization of discrete facts and understanding of abstract patterns. Females sometimes show less confidence about their ability to understand abstract scientific principles, even when understanding is equivalent, which may be influenced by societal stereotypes and educational experiences that discourage confidence in scientific subjects.

It is important to emphasize that the practical significance of the gender difference is modest. Female students in the metacognitive group still retained far more knowledge than females in the conventional lecture method group, clearly demonstrating that the metacognitive instructional strategy substantially benefits female students' retention, even if males benefit slightly more.

These findings, according to Hodson (2023), suggest that Chemistry educators implementing metacognitive strategies should be cognizant of potential gender differences and consider supplementary supports that may help female students fully optimize retention benefits, such as explicit discussions about gender stereotypes in science and opportunities to see role models successfully using metacognitive strategies.

CONCLUSION

Based on the findings of this study, it is concluded that the Metacognitive Instructional Strategy is a highly effective tool for improving academic achievement and retention in

Chemistry; significantly outperforming the traditional lecture-based method. However, contrary to the expectation of gender neutrality, the strategy was found to be more beneficial for male students than for female students in context. The significant interaction effects confirm that the efficacy of the Metacognitive instructional strategy (MIS) is not uniform across genders, indicating a need for pedagogical refinement to ensure it meets the learning needs of all students equitably. The following recommendations are made:

1. Chemistry teachers should adopt metacognitive instructional strategy in place of the conventional lecture method to improve students' achievement.
2. Teachers should provide additional scaffolding for female students to ensure they fully benefit from metacognitive learning activities.
3. Schools should integrate structured self-questioning and metacognitive monitoring checklists into chemistry lessons.
4. Curriculum planners should include metacognitive skill development as a core component of secondary school chemistry instruction.
5. Teachers should combine individual metacognitive activities with peer discussions to enhance retention for all students, especially females.
6. Regular low-stakes quizzes and periodic review sessions should be implemented to strengthen long-term retention of chemist.

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