Effect of Metacognitive Learning Cycle on Secondary School Students' Attitudes towards Chemistry in Federal Capital Territory, Abuja

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Abstract:

This study examined the effect of metacognitive learning cycle on secondary school chemistry students' attitudes towards chemistry in Federal Capital Territory, Abuja. It was guided by two research objectives, two research questions, and two null hypotheses. A quasi-experimental research design, incorporating a pretest and posttest, was used, with one experimental group and one control group. The study involved 10,755 SS2 chemistry students, from which a sample of 98 students (52 in the experimental group and 46 in the control group) was selected using purposive and random sampling techniques. The experimental group (25 males, 27 females) was taught using the metacognitive learning cycle, while the control group (20 males, 26 females) received instruction through the conventional teaching method. The intervention lasted eight weeks. Data collection was conducted using the Chemistry Attitude Scale (CAS), which had a reliability index of 0.92 (determined via Cronbach Alpha). Mean, standard deviation, and ANCOVA statistics were used for data analysis. Results indicated that the metacognitive learning cycle was more effective in improving students' attitudes toward chemistry than conventional teaching method. Additionally, there was no significant difference in attitude scores between male and female students exposed to the metacognitive learning cycle approach. Based on these findings, the study recommended adopting metacognitive learning cycle in chemistry instruction.

Keywords: Secondary School, Students, Attitude.

Introduction

Chemistry is a fundamental scientific discipline that explores the composition, structure, and intrinsic properties of matter, as well as the transformations it undergoes. It serves as a critical link between the physical and life sciences, offering essential knowledge for understanding the molecular mechanisms that govern the natural world. The applications of chemistry extend far beyond academic inquiry, influencing various aspects of daily life, from biological processes such as respiration and digestion to highly complex technological advancements in pharmaceuticals, environmental management, and industrial production. Given its broad significance, chemistry is a foundational subject for students pursuing careers in medicine, engineering, agriculture, pharmacy, and other science-related fields (Igbonugo, 2015). Recognizing the indispensable role of chemistry in national development, the Nigerian educational system mandates that a credit pass in chemistry is required for students intending to study science-based professions in the tertiary institutions.

The significance of chemistry is not confined to the academic sphere but extends to the broader context of national development. A well-trained workforce in chemistry-related fields is essential for fostering advancements in healthcare, environmental conservation, and industrial innovation. Chemistry drives progress in key areas such as agricultural productivity, energy generation, and material science, all of which contribute to economic growth and technological advancement. In Nigeria, the mastery of chemistry is viewed as a cornerstone of scientific education, underpinning the country's aspirations for sustainable development. However, despite its crucial role, many students struggle with chemistry due to various pedagogical and systemic challenges.

One of the primary obstacles to effective chemistry education is the widespread reliance on conventional teaching methodologies, commonly referred to as the "chalk-and-talk" approach (Abah, 2020). This traditional method is predominantly teacher-centered, where instructors deliver information through direct lecturing while students passively receive and memorize content. Although this approach offers a structured means of instruction, it lacks interactive engagement, making it particularly ineffective for subjects such as chemistry, which require critical thinking, problem-solving skills, and hands-on experimentation.

Metacognitive Learning Cycle (MLC) is an instructional strategy designed to enhance students' ability to regulate and reflect on their own learning processes. Metacognition, or "thinking about one's own thinking," plays a crucial role in deepening students' understanding and improving their problem-solving skills. By encouraging students to engage in self-reflection at every stage of learning, MLC fosters greater cognitive awareness and self-regulation, making the learning process more meaningful and effective.

The MLC framework comprises four distinct phases:

1. Concept Assessment – In this initial phase, students evaluate their pre-existing knowledge on a given topic, allowing them to identify gaps in their understanding.

2. Concept Exploration – This phase involves active student participation through experiments, investigations, and hands-on activities, enabling them to interact directly with the subject matter.

3. Concept Introduction – Here, teachers facilitate discussions that help students interpret their findings, guiding them toward a deeper comprehension of key concepts.

4. Concept Application – In this final phase, students apply their newly acquired knowledge to real-world scenarios, reinforcing their understanding and problem-solving abilities.

Except for the exploration phase, each stage incorporates metacognitive reflection, where students critically analyze their own learning through self-questioning and self-monitoring (Osuafor & Obimezie, 2021).

For the Metacognitive Learning Cycle to be successfully implemented, educators must possess a strong understanding of metacognitive strategies and be capable of modeling reflective thinking (Smith-Ferguson, 2020). Teachers should encourage students to engage in self-questioning, verbalize their thought processes, and participate in meaningful discussions. This requires a pedagogical shift from the traditional role of teachers as mere transmitters of knowledge to facilitators who actively engage students in the learning process. By fostering an interactive learning environment, teachers can enhance students' critical thinking abilities, problem-solving skills, and overall academic performance in chemistry.

Numerous studies have provided empirical support for the effectiveness of the Metacognitive Learning Cycle in improving students' academic performance in science subjects, including chemistry, physics, and mathematics. Research conducted by Osuafor and Obimezie (2021) demonstrated that students exposed to MLC-based instruction performed significantly better in mathematics than their counterparts taught using traditional methods. Similarly, Uzobuike and Okoli (2020) found that metacognitive strategies had a positive impact on student learning outcomes in physics. The reflective nature of MLC allows students to develop higher-order cognitive skills, leading to improved comprehension and retention of complex scientific concepts.

The benefits of adopting MLC in chemistry instruction are well-documented. According to Oyelekan, Jolayemi, and Upahi (2018), the use of MLC enhances students' self-efficacy and academic achievement. By promoting active engagement, fostering independent thinking, and encouraging self-regulation, MLC enables students to develop a deeper understanding of chemistry concepts. Additionally, incorporating hands-on experiments and reflective exercises helps bridge learning gaps, making it an effective strategy for students with diverse learning abilities.

Attitude refers to an individual's thoughts or feelings toward something, shaped by their beliefs and emotions, which influence their behavior in various situations (Ini-Ibehe & Mbuk, 2019). It represents an enduring evaluation of a person, object, or issue, classifying it as good or bad. Attitudes are developed rather than innate and can be altered over time.

Attitude is a multifaceted concept, with its expression evident in reactions and behaviors. Attitudes can be measured either through direct self-reporting or by analyzing spontaneous responses (Albarracin & Shavitt, 2017). They can be categorized as positive, negative, or neutral. Research by Malala, Onderi, and Ojowi (2021) found that a positive attitude towards a subject led to better academic performance, whereas a negative attitude resulted in lower performance. Their findings also indicated that students' attitudes were influenced by their academic success in a subject, and vice versa.

Several factors contribute to attitude development, including peer influence, conditioning, direct instruction, and modeling, which is a metacognitive strategy. Musengimana, Kampire, and Ntawiha (2021) identified instructional methods as a key factor affecting secondary school students' attitudes towards chemistry, emphasizing the importance of self-directed learning to foster positive attitudes and improve academic achievement. Similarly, it is argued that teachers' instructional styles significantly impact students' attitudes, as varied teaching approaches can enhance engagement and motivation in learning chemistry.

Encouraging students to actively participate in the learning process enhances their attitudes toward education. When students are given more autonomy over their learning, their engagement and attitudes improve (Hativa, 2016).

Students' attitudes toward chemistry encompass their enthusiasm, motivation, and self-confidence in learning the subject. Their response to chemistry instruction—whether positive, negative, or neutral—can provide insights into their academic performance (Abarro & Asuncion, 2021).

Metacognition, the ability to reflect on and regulate one's learning, is a key factor in effective science education (Nath, 2016). The metacognitive learning cycle is founded on this principle, and research suggests that metacognitive instruction in chemistry enhances students' attitudes toward learning the subject (Dike, Mumuni & Worukwu, 2017). This improvement is attributed to the fact that metacognitive activities encourage reflection and the formation of hypotheses and theoretical frameworks, which are fundamental to scientific inquiry (Abarro & Asuncion, 2021).

Siegesmund (2016) highlights that metacognition can alter students' study behaviors. Students who lack confidence tend to have lower attitudes toward science, but metacognitive scaffolding has been shown to boost their confidence in science learning (Wang, Chen & Yen, 2021). In mathematics education, students exposed to metacognitive teaching strategies developed a more positive attitude compared to those taught using traditional lecture methods (Udabah & Nneji, 2020). Similarly, chemistry students taught through metacognitive strategies demonstrated improved higher-order thinking skills (Parlan & Sri, 2021).

Motivation is a crucial factor in shaping students' attitudes, as higher motivation fosters a more positive outlook. Research by Rahmani and Samavi (2016) indicates that enhancing metacognitive skills can lead to increased academic motivation and improved performance in chemistry. Metacognition influences motivation by shaping students' chemistry identity, reducing burnout, and enhancing engagement in learning. By applying metacognitive strategies, students develop the ability to regulate their learning, which contributes to higher motivation and academic success. Students who exhibit both strong metacognitive skills and a positive attitude tend to achieve better results than those with weaker metacognition and a negative outlook (Owo & Ikwut, 2015).

Gender disparities in science education, particularly in chemistry, have been a subject of considerable debate. Some studies suggest that male students tend to outperform their female counterparts due to societal biases and entrenched stereotypes that discourage female participation in STEM disciplines. For instance, Ejedegbe (2016) reported that gender had a significant impact on students' chemistry achievement, with male students generally performing better. However, other research presents a different perspective. Ajayi and Ogbeba (2017) found that when students were taught using interactive and hands-on approaches such as MLC, gender-based differences in chemistry achievement became negligible. This suggests that implementing innovative teaching methodologies can help create a more equitable learning environment, mitigating the impact of gender-related disparities in STEM education. This study also aimed to examine the effect of gender on students' attitude in chemistry

Purpose of the Study

The purpose of this study was to examine the effect of Metacognitive Learning Cycle on secondary school chemistry students' attitude towards chemistry in Federal Capital Territory, Abuja.

Specifically, the objectives of the study were to determine:

(i) the difference between the attitude of students taught chemistry with Metacognitive Learning Cycle and those taught using the conventional teaching method;

(ii) the difference between the attitude of male and female students taught chemistry using Metacognitive Learning Cycle;

Research Questions

The study was guided by the following questions:

1. What is the difference in mean attitude scores between students taught chemistry using the Metacognitive Learning Cycle and those taught with the conventional teaching method?

2. What is the difference in the mean attitude scores of male and female students taught chemistry using Metacognitive Learning Cycle?

Hypotheses

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

Ho$_1$: There is no significant difference in the mean attitude scores of students taught Chemistry using the metacognitive learning cycle compared to those taught using conventional teaching] method

Ho$_2$: There is no significant difference between the mean achievement scores of male and female students taught chemistry using Metacognitive Learning Cycle.

Methodology

The study utilized a quasi-experimental research design, specifically a pretest-posttest non-equivalent, non-randomized control group approach. This design was selected to effectively assess causal relationships between dependent and independent variables while maintaining the natural school setting by using intact classes. The independent variable was the teaching approach, which included the metacognitive learning cycle and the conventional teaching method. The dependent variable was students' attitude toward Chemistry, with gender included as a moderating factor.

The study population consisted of 10,755 Senior Secondary 2 (SS2) Chemistry students in public secondary schools within the Federal Capital Territory (FCT), Nigeria, according to the FCT Secondary Education Board (2024). A sample of 98 SS2 Chemistry students (45 males and 53 females) was drawn from two randomly selected public schools in the FCT through a multi-stage sampling technique:

1. Purposive Sampling: Co-educational schools were selected to ensure gender representation.

2. Random Selection of Schools: Two co-educational schools were chosen.

3. Selection of Intact Classes: One chemistry class from each school was randomly selected.

4. Assignment of Groups: The classes were assigned to either the experimental or control group through a coin toss.

The sample distribution was as follows:

Group	Male	Female	Total
Experimental Group	25	27	52
Control Group	20	26	46
Total	45	53	98

The research instrument, the Chemistry Attitude Scale (CAS), was adapted from Akudo (2018). It consisted of 20 items designed to gauge students' attitudes toward Chemistry. Responses were measured on a 4-point Likert scale:

Strongly Agree (SA) = 4,

Agree (A) = 3,

Disagree (D) = 2,

Strongly Disagree (SD) = 1 (scoring was reversed for negative statements).

The CAS was administered before (pretest) and after (posttest) the instructional intervention to assess students' attitudes toward Chemistry before and after exposure to the Metacognitive Learning Cycle and Conventional Teaching Method.

Lesson plans were prepared for both teaching approaches to ensure instructional consistency. To establish the instrument's validity, three experts—two in Science and Environmental Education and another in Educational Foundations—evaluated the CAS for face, content, and construct validity, ensuring clarity and alignment with study objectives.

A pilot test was conducted with 20 SS2 Chemistry students from a school within the study population but not included in the sample. Reliability was assessed using Cronbach's Alpha, yielding a coefficient of 0.92.

To ensure the effective implementation of the teaching methods:

1. Chemistry teachers from the selected schools were trained as research assistants.

2. Training was conducted one week before the experiment to familiarize them with the lesson plans.

3. Students in the experimental group received instruction based on the metacognitive learning cycle, while the control group was taught using the conventional method.

4. The instructional intervention lasted eight weeks, following this sequence:

(i).   Pretest Administration: Measured students' initial attitude toward Chemistry.

(ii).   Implementation of Teaching Methods:

        •Experimental Group: Taught using the metacognitive learning cycle.

        •Control Group: Taught using the conventional method.

(iii).   Posttest Administration: Evaluated students' attitude after the intervention.

The data collected were analyzed using both descriptive statistics of mean and standard deviation and inferential statistics of Analysis of Covariance (ANCOVA).

Presentation of Results

Research Question One:

What is the difference in mean attitude scores between students taught chemistry using the Metacognitive Learning Cycle and those taught with the conventional teaching method?

To address this question, the mean score was analyzed, as shown in the table 1 below:

Table 1: Mean Attitude Scores of Experimental and Control Groups in the CAS

Groups	N	Pre-attitude Mean	Post-attitude Mean	Mean gain
Experimental	52	48.10	61.30	13.20
Control	46	51.20	52.20	1.00
Mean rank diff.		-3.10	9.10	12.20
Total	98			

Table 1 displays the mean scores for students' attitudes in both the experimental and control groups. The experimental group had a pre-attitude mean of 48.1, which increased to 61.3 after the intervention, resulting in a mean gain of 13.2. Meanwhile, the control group had a pre-attitude mean score of 51.2, which slightly increased to 52.2, leading to a mean rank gain of only 1.0. The difference in post-attitude mean scores between the experimental and control groups was 9.1, favoring the experimental group. This variation suggests that students exposed to the Metacognitive Learning Cycle demonstrated a more positive attitude toward chemistry compared to those taught using the conventional method.

Research Question Two:

What is the difference in the mean attitude scores of male and female students taught chemistry using Metacognitive Learning Cycle?

Mean scores for both groups were used in answering this question as shown in table 2 below:

Table 2: Mean Attitude Scores of Experimental Group Male and Female Students in the CAS

Groups	N	Pre-attitude Mean	Post-attitude Mean	Mean Gain
Male	25	48.80	60.40	11.60
Female	27	47.60	62.10	14.50
Mean diff.		1.20	-1.70	-2.90
Total	52			

The table shows that male students had a pre-attitude mean of 48.8 and a post-attitude mean of 60.4, resulting in a mean gain of 11.6. Female students had a pre-attitude mean of 47.6 and a post-attitude mean of 62.1, leading to a mean gain of 14.5. The difference in attitude mean scores between male and female students after being taught chemistry using the Metacognitive Learning Cycle was -1.7. This suggests that gender does not significantly influence students' attitudes toward chemistry.

Tests of Hypotheses

Hypothesis One

HO$_1$:

There is no significant difference in the mean attitude scores of students taught Chemistry using the metacognitive learning cycle compared to those taught using conventional teaching method.

To evaluate this hypothesis, an Analysis of Covariance (ANCOVA) was conducted on students' attitude mean scores from both the experimental and control groups. The results are summarized in the table below:

Table 3: Summary of Analysis of Covariance (ANCOVA) of Experimental and Control group in CAS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3770.721[a]	2	1885.36	105.530	.000	.690
Intercept	751.484	1	751.484	42.063	.000	.307
PreCAS	1770.819	1	1770.89	99.119	.000	.511
Attitude	2870.749	1	2870.79	160.685	.000	.628
Error	1697.238	95	17.866			

Total	324098.00	98				
Corrected Total	5467.959	97				

a. R Squared = .690 (Adjusted R Squared = .683)

The table shows the post-intervention attitude mean scores for students in the experimental and control groups. The F-value of 160.685 with a p-value of 0.00 ($p < 0.05$) indicates that the effect of the metacognitive learning cycle on students' attitudes toward Chemistry was statistically significant. Since the p-value is lower than the alpha level of 0.05, the null hypothesis is rejected. This implies that the metacognitive learning cycle had a significant positive impact on students' attitudes toward Chemistry compared to the conventional teaching method, as indicated by the mean rank scores favoring the experimental group.

Hypothesis Two

HO$_2$:

HO$_2$: There is no significant difference between mean attitude scores of male and female students taught Chemistry using metacognitive learning cycle.

To assess this, an Analysis of Covariance (ANCOVA) was conducted on the mean attitude scores of male and female students. The findings are summarized in Table 4 below:

Table 4': Summary of ANCOVA of Mean Attitude Scores of Male and Female Students in the Experimental Group

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	67.074[a]	2	33.537	1.963	.151	.074
Intercept	1510.663	1	1510.663	88.421	.000	.643
Pre	14.128	1	14.128	.827	.368	.017
Gender	61.068	1	61.068	3.574	.065	.068
Error	837.157	49	17.085			
Total	196108.00	52				
Corrected Total	904.231	51				

a. R Squared = .074 (Adjusted R Squared = .036)

Table 4 presents the ANCOVA results for the mean attitude rank scores of male and female students who were instructed using the metacognitive learning cycle. The results show $F_{(1, 51)} = 3.574$, $P = 0.065$, which is greater than the alpha level of 0.05. Consequently, the null hypothesis is retained, indicating that there is no significant difference in the attitude levels of male and female students exposed to the metacognitive learning cycle. This suggests that the metacognitive learning cycle is equally effective for both genders.

Discussion of Findings

This study investigated the effect of the metacognitive learning cycle approach on the attitudes of secondary school chemistry students towards chemistry in Federal Capital Territory, Abuja. According to the findings, there was a statistically significant difference between the mean attitude scores of students taught using the metacognitive learning cycle approach and those instructed through conventional teaching method. The results demonstrated that students exposed to the

metacognitive learning cycle approach achieved higher mean attitude scores compared to those who underwent conventional teaching. Consequently, the null hypothesis was rejected.

The findings further suggest that the metacognitive learning cycle approach effectively enhanced students' attitudes toward chemistry in the experimental group, leading to a considerable increase in their mean score. In contrast, the control group, which was taught using conventional method exhibited only a slight increase in mean score. Overall, the data indicated that the metacognitive learning cycle approach had a significant positive impact on students' attitudes, while the traditional teaching method resulted in minimal improvement. This highlights the pivotal role of the metacognitive learning cycle in fostering a more positive attitude toward chemistry.

The findings of this study align with the findings of Yunus and Ali (2021), who established that a teacher's instructional approach plays a crucial role in shaping students' attitudes toward learning chemistry. Furthermore, the results are consistent with Hativa (2016), who emphasized that providing students with opportunities to take charge of their own learning—such as through the autonomy offered by the metacognitive learning cycle approach—leads to improved attitudes. Additionally, the study supports the work of Udabah and Nneji (2020), which found that students who were taught mathematics using a metacognitive teaching strategy exhibited a more positive attitude toward the subject compared to their peers who were instructed using conventional lecture-based methods.

The findings revealed that there was no statistically significant difference in the mean attitude scores between male and female students taught chemistry using the metacognitive learning cycle approach. Both male and female students in the experimental group showed improved attitudes toward chemistry, with no notable gender-based differences. The mean scores of both genders increased, indicating that the intervention was beneficial to both male and female students. This finding is consistent with the conclusion of Sugano and Mamolo (2021), who asserted that students' attitudes toward a subject are influenced by instructional methods rather than gender. Additionally, it aligns with the research of Musengimana, Kampire, and Ntawiha (2021), which concluded that teaching methodology is a key factor affecting the attitudes of both male and female secondary school students toward chemistry.

Conclusion

This study's findings indicate that employing the metacognitive learning cycle in chemistry instruction significantly enhances students' attitudes. Additionally, the absence of notable gender differences suggests that both male and female students can benefit from this approach equally, ensuring an unbiased and effective learning experience.

Recommendations

Based on the findings, the following recommendations were proposed:

1. The Federal Ministry of Education should advocate for the integration of the metacognitive learning cycle approach in secondary school chemistry instruction to enhance students' attitudes

2. Regular professional development programs should be organized for chemistry teachers to ensure they effectively implement metacognitive strategies, thereby improving student engagement and outcomes.

3. Educational policymakers should embed metacognitive learning strategies within the national chemistry curriculum to facilitate consistent application across all schools.

4. Given that no significant gender-based differences were identified in students' attitudes, schools should ensure equitable access to metacognitive learning cycle strategies for both male and female students.

5. Clear instructional guidelines and resources should be provided to teachers to support the seamless integration of the metacognitive learning cycle approach into chemistry lessons.

6. Educational stakeholders should develop textbooks, workbooks, and digital learning resources that align with the principles of the metacognitive learning cycle.

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