Educational Advancement and Development Journal (EADJ)
Volume 1 Number 2 December 2025, pp 73-84
E-ISSN: 3104-8390
https://neadafrica.com/journals/neadj

Effect of Four Modes Application Technique on Science Secondary School Students' Knowledge Retention in Chemistry

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Abstract

The paper investigated the effects of Four Modes Application Technique (4MAT) on improving science learners' knowledge retention in Chemistry in Maiduguri Metropolis, Borno State Nigeria. The paper answered two research questions and tested two hypotheses. A quasi-experimental design was employed, specifically pre-test-posttest-post-posttest nonequivalent group design. The study sample consisted of 115 SS II Chemistry students, divided into an Experimental group (56 students) and control group (59 students) sampled through simple random sampling technique. Chemistry Achievement Test (CAT) with a reliability of 0.90 served as a data collection instrument. Treatment group was instructed using 4MAT method, while the Control group received instruction via lecture method. Data were analyzed using Mean, standard deviation and Analysis of Covariance (ANCOVA). The results of the study revealed that there was a significant difference in knowledge retention favoring the experimental group. The study recommends adopting 4MAT teaching strategy in Chemistry education to enhance students' retention without gender disparity.

Keywords: Chemistry; Chemistry learning activities; knowledge retention; 4MAT; Gender

History:
Received : October 6, 2025
Revised : October 27, 2025
Accepted : November 30, 2025
Published : December 31, 2025
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Publisher: Network for Educational Advancement and Deve lopment

INTRODUCTION

Chemistry is the science of chemical composition of matter and changes it undergoes. Omiko (2014) defined Chemistry as a field of science that helps individuals understand the nature, composition and usefulness of both natural and man-made materials. Most daily activities are chemistry products (Umate**,** *et al*., 2022). Umate (2024) argues that Chemistry has positive impacts on the life of people and the development of a nation. Udofia and Ekong (2017) note that Chemistry is key driver of developments in the modern society since it is the bedrock of scientific and technological advancement. This is evident in the widespread uses of Chemistry across various areas of specialization, such as engineering, industry, space science, the military, pharmaceutical, and transportation, among others.

Despite the wide applications of Chemistry in various fields, students' academic achievement in the subject has remained poor for years, as reported by West African Examination Council (WAEC, 2013-2024) and several studies (Umate et al., 2021; Eya et al.,2020). Table 1 displays Borno state science students' performance in Chemistry from 2013-2024, showing that only 30% of the students achieved a credit and above. This, in turn, prevents the students from getting admission into universities and other tertiary institutions, as chemistry is a prerequisite subject and must be scored at least a credit level pass. However, on average

about 70% of the students scored chemistry below credit level which disqualifies them from getting admission into tertiary institutions.

Table 1: Students' Chemistry WAEC Result for the years 2013-2024 in Borno State, Nigeria

Year	Candidate Registered	Passed	% Passed	Failed	%Failed
2013	6,217	1,532	25%	4,685	75%
2014	3,585	515	14%	3,070	86%
2015	5,660	1,017	18%	4,643	82%
2016	1,472	503	34%	969	65%
2017	7,188	1,774	25%	5,414	75%
2018	12,327	2,567	21%	9,760	79%
2019	13,622	3,236	23%	10,386	73%
2020	11,298	3,221	28%	7,177	72%
2021	13,464	3,983	29%	8,481	71%
2022	14,544	4,672	32%	9872	68%
2023	13,987	4234	31%	9753	69%
2024	15,723	5432	34%	10,291	64%

Source: Educational Resource Centre, (ERC), Maiduguri, Borno state, 2024

Studies on students' poor performance in Chemistry examinations identified many contributing factors including abstract nature of chemistry concepts (Umate, et al., 2022; Olorundare, 2014), Poor teaching methods used by the teachers (Niyonsaba et al., 2022)), improper linking of practical idea to theoretical idea (Eya & Umate, 2020) and students' inability to retain what they were taught for long periods (Disawat & Mahapoonyanont, 2025). Retention is of interest to this investigation and very essential in learning for a better learning outcome.

Retention is a person's ability to recall learned experiences, activities and ideas after sometimes. According to Oyeyemi and Oyakhirome (2024)**.** Retention is the process of retaining new acquired information, experiences or part of it without forgetting it easily. As an essential aspect of learning, retention plays a critical role in human learning. Disawat and Mahapoonyanont. (2025). emphasized by stating "no retention, no learning, and if there is no learning, there is nothing to maintain and recall. A major contributory factor to students' poor academic achievement in Chemistry is attributed to their inability to retain what they were taught for long periods (Disawat & Mahapoonyanont, 2025; Lasis, et al., 2016).

To improve the students' outcomes in Chemistry, there is a need to adopt teaching strategies that could enhance students' knowledge retention, enabling students to retain what they have being taught to them for extended periods. Several studies revealed that active, engaging and effective teaching strategies can improve knowledge retention (Umate, *et al*, 2024; Oyeyemi & Oyakhirome,2024). Niyonsaba *et al,* (2022) argued that science teaching should incorporate hand-on activities such as touching, classifying, manipulating and observing, to help students understand scientific processes. One of such strategies is Four Mode Application Technique (4MAT), which promotes active participation through interaction between students and teacher.

4MAT is a teaching strategy developed by McCarthy in 1987, based on concept of learning styles and brain hemisphere functions (Serap & Sengul, 2013). It creates a learning environment in cyclic form through an 8-step lesson plan that is followed in this sequence (1) create an experience, (2) examine, (3) image, (4) define, (6) try, (7) extend and (8) integrate (Nikolaou & Koutsouba, 2012). This approach capitalizes on individual learning style and brain dominance processing preferences. 4MAT operates on the principle that individual differs genetically, resulting in differences in how they perceive and process new information

during learning. In addition, human brain is divided into left and right hemispheres, each with distinct functions (McCarthy & McCarthy, 2006).

4MAT advocates that there are four types of learners in a normal classroom setting, and when designing learning activities, educators must adequately address these learners' needs. Protootong (2011) identifies these four types of learners as: Type 1 (Imaginative), Type 2 (Analytic), Type 3 (Common Sense) and Type 4 (Dynamic) learners. Type 1 learners seek concrete experience and abstract conceptualization (asking "why?) Type 2 learners prefer abstract conceptualization and reflective observation (asking "What"?). Type 3 learners seek abstract conceptualization and active experimentation (asking "How"?). Type 4 learners engage with concrete experience and active experimentation (asking "what if"?) (Teczan & Guvenc, 2017; Nurman, 2015). The human brain is anatomically divided into left and right parts, which are physiologically different from each other. The left brain is analytical, systematic, looks at part, rational while the right brain is intuitive, random, holistic, and creative (Humera, 2015; Geak, 2011). In 4MAT model, learning activities are delivered in a manner that addresses individual styles while incorporating function of both left and right brain.

Numerous studies conducted on 4MAT teaching strategy across the world have examined its ability to improve students' success in science subjects. For example, Ibenegbu, (2014) found that 4MAT teaching strategy improved Biology students' retention in Ebonyi State. Similarly, Jack and Zubairu (2021) discovered that 4MATt enhanced students' success in Chemistry in Jalingo, Taraba State. Ahmad and Umate (2019) conducted a meta-analysis on 4MAT and found that this teaching strategy improved students' outcomes in science subjects. Furthermore, Abdelsalam (2017) reported that 4MAT improved the learning outcomes of Jordanian high school students in science. Sibel and Sabiha, (2016) revealed that 4MAT was effective in improving Turkish students' achievement and retention. Osama, Fahad and Ayman (2016) disclosed that Saudi Arabian students taught using 4MAT exhibited high academic achievement and retention. Finally, Nurma (2015) found that 4MAT improved students' academic success in Thailand.

4MAT teaching strategy has been successful in improving students' learning outcomes across different regions. Based on previous studies and given absence or scarcity of studies on 4MAT teaching strategy in chemistry education. As a result, this paper intends to determine the efficacy of 4MAT teaching strategy in improving students' knowledge retention, while also considering gender differences. Specifically, this study developed concrete Chemistry learning activities based on 4MAT, which were then taught to experimental group. The objectives were to evaluate the strategy's effectiveness in enhancing retention and potential variations by gender.

The gender differences in students' academic success have been a prominent topic in contemporary educational research worldwide (Nguru, 2023). Prior studies present conflicting findings: Some revealed that female students outperformed males in both achievement and retention (Jackman & Morrain-Webb, 2019; Adeyemi &Ajibade, 2011), while others reported the opposite pattern (Wrigley-Asante *et al*., 2023; Nguru, 2023; Owino, & Othuon, 2023; Abuh, 2021). Nevertheless, other studies have found no significant difference in academic success across students' gender in various science subject (Yuorsuu, *et al*, 2025; Shawai *et al*., 2022; Gambari, *et al*., 2017; Oluwatosin & Ogbeba 2017).

Considering these contradictory results regarding gender and academic outcomes, this study seeks to resolve these discrepancies by providing additional clarity. Thus, this study

implemented Chemistry learning activities based on 4MAT with an experimental group, aiming to examine the efficacy of AMAT on retention in Chemistry and how gender influences the strategy's efficacy in improving knowledge retention.

Purpose of the Study

The main purpose of this study is to examine the effect of four modes application technique on science secondary school knowledge retention in chemistry. Specifically, the study sought to examine:

1. The mean retention score of secondary school Chemistry students taught using 4MAT teaching strategy and conventional methods of teaching

2. The mean retention score among secondary school Chemistry students when taught using 4MAT teaching strategy.

Research Questions

1. What is the mean retention scores of secondary school chemistry students taught using 4MAT teaching strategy and conventional method of teaching?

2. What is gender difference in retention scores of secondary school chemistry students taught using 4MAT teaching strategy

Hypotheses

HO_1: There is no significant difference between mean retention scores of secondary school Chemistry students taught using 4MAT teaching strategy and conventional methods of teaching

HO_2: There is no significant gender difference in mean retention scores of the secondary school Chemistry students when taught using 4MAT teaching strategy

METHODOLOGY

A pretest-post-test-post-posttest quasi-experimental research design was employed. The design was used to continue with the normal lesson of the sampled schools. This approach aligns with the studies conducted by Abdelsalam, 2017; Sibel and sabiha , 2016; and Okoyefi, 2014).

The population consisted of 1794 (907 males and 887 females) Senior Secondary II students from seven co-educational schools in Maiduguri Metropolis, Borno state Nigeria (Borno State Ministry of Education, 2018). The sample made up of 115 (56 females; 59 males) SS II secondary school students. One intact class (N=56; 26 females; 30 males) from a selected School served as an experimental group. Another intact class (N=59; 30 females; 29 males) from a different school served as a control group. A multistage sampling procedure was used in the study. In the first stage, a purposive sampling technique was used select coeducational schools as study required inclusion of both male and female students. In the second stage, a simple random sampling technique was used to draw two schools from the identified coeducational schools. In the third stage, the simple random sampling technique used to draw one intact class from each of the sampled schools. Finally, the simple random sampling technique was used assigned experimental and control groups to the sampled schools.

The topics Oxidation and Reduction reaction, Rates of Chemical reaction and Chemical equilibrium were used in preparing lesson plans for the Experimental and control groups. These topics were chosen because they are widely perceived as difficult Chemistry concepts, as reported by Lajium, (2015), Karpuewan, et al., (2015) and WAEC Chief Examiner's, (2020).

Chemistry Achievement Test (CAT) containing 30 multiple choice items (4-options each) was employed as instrument. The items of CAT were adapted from past WAEC Chemistry examinations. The CAT was validated by subject and measurement evaluation experts. A pilot test was carried out with thirty (30) SS2 Chemistry students to assess the instrument. The pilot test scores were used to established internal consistency reliability, which was calculated at 0.90 using Kuder-Rechardson Formula 20 (K-R20).

Pre-test administered to both treatment(experimental) and comparison (control) groups using Achievement Test (CAT). The experimental group received experimental intervention with chemistry learning activities in line with 4MAT using topics selected for the study (Appendix A, page 12, for a sample of the lesson plan prepared in line with the 4MAT under the topic of the oxidation reaction). The control group received instruction on the same topics but via lecture-based methods. The intervention lasted six weeks for both groups, after which a post-test was administered using the CAT. All scripts were scored according to the CAT marking scheme and recorded. Two weeks after, a reshuffled version of the CAT was administered as a retention test to assess knowledge retention.

Mean and standard deviation were employed to answer research questions, while Analysis of Covariance (ANCOVA) at 0.05 significant level was used for testing hypotheses. The post-test scores of the students served as covariate in the ANCOVA for knowledge retention analysis

RESULTS

Research Question One:

What is the difference between mean retention scores of secondary school chemistry students taught using 4MAT teaching strategy and conventional method of teaching?

Table 2: Mean Retention Scores of Chemistry Students Taught Using 4MAT and Conventional Teaching Methods

Group	N	Posttest		Retention		Gain Scores
		Mean	SD	Mean	SD	
Experimental	56	21.30	4.40	19.30	2.88	2.00
Control	59	16.20	2.40	14.60	1.59	1.60

Table 2 shows that the students taught using 4MAT achieved a post-test score of 21.30 (SD= 4.40) and a retention mean score of 19.30 (SD = 2.88), resulting in a mean gain of 2.00. In comparison, students received instruction using conventional method had a post-test mean score of 16.20 (SD =2.40) and a retention mean score of 14.60(SD=1.60), yielding a mean gain of 1.60. The mean difference between the two groups was 4.70, favouring 4MAT teaching strategy. This shows that 4MAT approach enhanced knowledge retention more effective than the conventional method of teaching.

Research Question Two:

What is the gender difference in retention scores of secondary school chemistry students when taught using 4MAT teaching strategy?

Table 3: Mean Retention Scores of Males and Females Chemistry Students taught using 4MAT Teaching Strategy

Gender	N	Posttest		Retention		Gain Scores
		Mean	SD	Mean	SD	
Male	30	21.47	4.65	19.70	2.45	1.77
Female	26	21.04	4.07	18.80	3.29	2.24

Table 3 presents the students' knowledge retention results by gender. The results show that male students taught using 4MAT achieved a post-test score of 21.47 (SD =4.65) and a retention mean score of 19.70 (SD=2.45), resulting in a mean gain of 1.77. Female students, in comparison, had a post-test mean score of 21.04(SD= 4.70) and a retention mean score of 18.80 (SD=3.29), producing a mean gain of 2.24. The mean difference between the two groups was 0.9 in favor of female students, suggesting that female slightly performed better than male students in the experimental group. However, this difference was not statistically significant. This suggests that 4MAT teaching strategy enhanced students' knowledge retention regardless of the gender.

Hypotheses

Ho_1: There is no significant difference between mean retention scores of secondary school chemistry students taught using 4MAT teaching strategy and conventional method of teaching.

Table 4: Analysis of Covariance of Students' Mean Retention Scores in Chemistry Tests of Between-Subjects Effects

Dependent Variable: postposttest Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	692.826[a]	4	173.206	35.237	.000	
Intercept	1534.737	1	1534.737	312.224	.000	
Posttest	51.779	1	51.779	10.534	.002	
Gender	2.132	1	2.132	.434	.512	NS
Method	585.405	1	585.405	119.094	.000	S
Gender * Group	16.514	1	16.514	3.360	.070	
Error	540.704	110	4.915			
Total	34028.000	115				
Corrected Total	1233.530	114				

a. R Squared = .562 (Adjusted R Squared = .546), S= Significant NS= Not significant

The results of in Table 4 show at 0.05 significant level, the calculated F-value (1,110) =585.405, $p < 0.05$. Therefore, the null hypothesis was rejected, indicating a statistically significant difference in students' knowledge retention favoring those taught using 4MAT teaching strategy.

Ho_2: There is no significant gender difference in mean achievement scores of the secondary school chemistry students when taught using 4MAT teaching strategy.

The results in Table 4 also show that at 0.05 significance level, the calculated F(1,110) =0.434 , $p > 0.05$. Therefore, the null hypothesis was accepted, indicating no statistically significant difference in mean retention scores between male and female students taught chemistry concepts using 4MAT teaching strategy.

Discussion

The findings of this study revealed a statistically significant difference in mean retention scores between chemistry students taught using the 4MAT and those taught via

conventional teaching methods, favoring the 4MAT approach. This suggests that the 4MAT teaching strategy enhances the students' retention of Chemistry concepts. This finding aligns with the findings prvious studies (Disawat & Mahapoonyanont, 2025; Jack & Zubairu, 2021; Abdelsalam, 2017, Sibel & Sabiha, 2016; Kanadi, 2016; Nurman, 2015) that similarly found superior knowledge retention in the experimental groups. This outcome may be attributed to the distinctive delivery method of 4MAT approach. The strategy ensured active participation, incorporated activities stimulating both left and right brain function in the chemistry materials and included memorable events designed to facilitate recall-consistent with the principles outlined by Lasis, Alabi and Salaudeen (2016) and Okurumeh, (2016)

This study also revealed no significant gender difference in the mean retention scores among chemistry students exposed to the 4MAT teaching strategy. This finding clearly indicates that male and female Chemistry students' equal performance when learning concepts through 4MAT approach. This result aligns with previous studies (Jacob & Linus, 2017; Okoyefi, 2014; Oluwatosin & Ogbeba, 2017) which also found no significant gender differences in the science students' academic achievement. This result may stem from the instructional method employed in the 4MAT-based chemistry lessons. Both male and female students were given equal opportunity for actively participation, consistent with feminist gender theory. In addition, individual differences were taken into consideration during instruction.

CONCLUSION

This study found that Students taught Chemistry concepts using the 4MAT approach demonstrated better concept retention than their counterparts taught through conventional methods. The findings also suggest that 4MAT teaching strategy improves students' performance regardless of gender. The Evidence from this study suggests that 4MAT teaching strategy could be adopted for teaching Chemistry concepts. This is because the strategy's core emphasizes presenting each in a concrete form, relating to everyday activities, building on students' prior knowledge and ensuring active participation from all students, regardless of gender.

RECOMMENDATIONS

The study recommends that Chemistry teachers should implement the 4MAT teaching strategy in their instruction, as it may improve students' retention which may enhance performance in Chemistry without gender disparity. The findings of this study will be shared with science teachers through workshops, seminars, conferences and publications, helping them recognize the benefits of the 4MAT teaching method in science education. By adopting this strategy, teachers can enhance students' knowledge retention while ensuring equal learning opportunities for gender.

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