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Effect of Mind-Mapping Strategy on Senior Secondary School Chemistry Students' Academic Achievement and Critical Thinking

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Abstract: *This study examines the effects of a mind-mapping instructional strategy on senior secondary school chemistry students' academic achievement and critical thinking. Six hypotheses were formulated and analysed. A quasi-experimental, non-equivalent pre-test, post-test, control group design using a 2 x2 factorial design was adopted for the study. The population of this study comprises a total of 19,409 SS II students offering Chemistry in all the government-owned secondary schools in Delta State for the 2021/2022 session. A sample of 48 SS2 students was drawn from two secondary schools in Delta State. The purposive non-randomized sampling technique was used for the selection of the schools. The instruments that were used for the study were the Chemistry Achievement Test (CAT) and a questionnaire titled "Students' Critical Thinking Scale" (SCTS). The validity and reliability of the instruments were determined. The face and content of the instruments were determined. The reliability of the instruments was also determined and the internal consistency reliability coefficient obtained for the CAT and SCT were 0.87 and 0.89 respectively. The data collected were analyzed using independent t-test and ANCOVA at 0.05 level of significance. The findings of the study among other showed there is a significant difference in the mean achievement scores of students taught chemistry using the mind mapping instructional strategy and those taught using the conventional method. There is no significant difference in the mean achievement scores of male and female students taught chemistry using a mind-mapping instructional strategy; there is a significant difference between the critical thinking scores of students taught chemistry using a mind-mapping instructional strategy and those taught using the conventional method. In line with the findings of this study, it could be concluded that the use of mind mapping instructional strategy enhanced chemistry students' academic achievement and critical thinking better than the conventional method. Based on the findings of this study, it was recommended among others that in the classroom, chemistry teachers should aim to introduce students to mind mapping as an instructional method that promotes and encourages active engagement in learning, learning by doing, and learning by experience.*

Keywords: Mind-Mapping, Instructional Strategy, Chemistry, Academic Achievement, Critical Thinking

INTRODUCTION

Background to the Study

Chemistry is fundamental to every aspect of life. Chemistry as an academic discipline deals with the properties and composition of matter, including its chemical reactions, structure, and associated changes. It is primarily concerned with atoms and their interactions with other atoms, and particularly with the properties of chemical bonds. Chemistry is a science springing from the principles of physics with applications in other sciences such as life sciences, engineering, technology, earth sciences, and medicine (Suchocki, 2014; Abanikannda, 2016). Chemistry graduates work all over the world in pharmaceutical and metallurgical firms, commercial laboratories, scientific research institutes, forensic scientists in the criminal justice system, universities, health services, food processing, petroleum and petrochemical industries, biotechnology, toxicology, hazardous waste management, manufacturing industries, mining and extractive industries, medical technology, agriculture, and forestry (Ababio, 2013; Helmenstine, 2019). The interdisciplinary nature of chemistry also lends its graduates to collaborating with engineers, physicists, and biologists in proposing solutions to a wide spectrum of societal problems. Chemistry is globally adjudged a prerequisite subject for the study of engineering, medicine, and other basic and applied science courses in any tertiary institution. According to Oloruntegbe and Oduntuyi (2008), a student who struggles in chemistry but excels in other science courses will find it difficult to study science-related courses like medicine and engineering at a tertiary institution. Chemistry is a subject with such practical and intellectual value that it cannot be overstated. It ranges from its contribution to the nation's economy, development, and industrialization to the enhancement of people's aesthetic value. The use of innovative teaching methods in the teaching and learning of chemistry in secondary schools, which is a core science subject, helps students get into many professional fields, like nursing, medicine, pharmacy, agriculture, engineering, and geology.

Despite all of the benefits of chemistry, students' academic achievement in chemistry on the senior secondary school certificate examination has remained low over the last few decades. This has caused widespread concern among educators and other stakeholders in the field of education. In a typical educational setting, parents, educators, and even students themselves want their children to perform better academically. There are numerous factors that contribute to students' academic success. One of the factors

is teachers' instructional strategies and students' ability to think critically while learning. Teachers use instructional strategies to help students become strategic learners. These strategies become learning strategies when students choose appropriate strategies on their own and use them effectively to complete tasks or meet goals. Using instructional strategies, students can be motivated and assisted in focusing their attention. By organizing information for understanding and remembering, you can monitor and assess learning. Throughout the years, many instructional strategies have been identified and tested. While many have been dismissed as unsuitable for science education, a select few have proven to be extremely successful. Teaching methods are known to influence students' skill acquisition and cognitive achievement in a variety of subject areas. As a result of their teacher's method(s), students can develop an innate interest in a subject. According to Nwadiani and Ugolo (2011), one of the major factors contributing to students' academic achievement is the instructional strategies used by instructors in the teaching of a given curriculum. Academic achievement assesses how well a student performed in a specific set of tasks that were assigned to them. Academic achievement refers to how students manage their studies and cope with or complete various assignments assigned to them by their lecturers over the course of a semester or academic year. Academic achievement refers to the overall marks, scores, and grades that teachers assign to students based on their academic progress in a variety of subjects. The scores of students reflect their intellectual capacity and academic standing. It is also a predictor of institutional performance, an indicator of educational quality, and a major factor in the well-being of youths and the nation as a whole (Lewin, Wasanga, & Somerset, 2011). Many instructional strategies have been identified and tested over the years in the course of teaching of Chemistry. While many have been deemed unsuitable for learning at the secondary education level, a few remain relatively effective in improving students. Instructional and learning strategies are known to make a significant contribution to students' skill acquisition and cognitive attainment in various school subject. Because of the strategy used by their teachers, students can develop an intrinsic interest in a given subject. However, it appears that some teachers lack a clear understanding of the appropriate instructional strategy that can be used to improve the teaching-learning of chemistry, as such teachers frequently rely on the use of lecture instructional strategy.

The lecture instructional strategy is a teaching strategy in which the teachers presents a verbal discourse on a particular subject, theme, or concept to the learners. The teachers deliver preplanned lessons to the students with little or no instructional materials (Nwagbo & Chikelu, 2011). It appears that the lecture instructional strategy is the most prevalent instructional strategy that most secondary schools' teachers often employ in teaching science. The lecture instructional strategy adopted in the teaching of science subjects has been designated as a teacher-centre approach. A teacher-centre approach is an instructional strategy where a teachers' functions in the familiar role of a classroom teacher, presenting information to the students, who are expected to passively receive the knowledge being presented. This method makes the teachers feel in-charge in the classroom setting.

The lecture strategy is a set of actions or activities organised by the teacher and delivered to the student in a methodical manner to enable him to acquire and process knowledge, retain and recall it, and apply it to new life tasks and issues. The lecture strategy was one of the most popular and fastest modes of disseminating knowledge, and it was frequently used in traditional classroom instruction. Learners who do not know how to be active participants in lectures have relied on dictation, copying directly from textbooks or chalkboards, memory, and repetition for learning. Researchers such as Wanjohi (2016) and Tao (2011) advocated the use of lectures, but stressed that the issue stems from how they are delivered, not from their fundamental incapacity to produce meaningful learning. In practise, most lectures fail to engage students or drive them to take ownership of their learning (Andala and Ng'umbi, 2016). When students who have learnt through lecture strategy are assessed in class, they appear to be more adept at applying what they have learned in immediate problem-solving situations (Tao, 2011). This is due to a lack of conceptual understanding of the ideas. The technique has also been found to encourage "rote" learning, which might result in the correct response without the capacity to explain why a certain concept was employed. Kukuru (2012) stated that using a lecture instructional strategy to convey knowledge to the learners should be avoided since it only provides weak education and learning capabilities. One of the instructional strategies that could be used to facilitate the teaching and learning of science subjects, particularly in w in secondary school, is the use of mind mapping.

A mind-mapping instructional strategy is an instructional strategy that makes use of a visual and non-linear representation of concepts and their relationships used in education. It is a student-centered educational technique that emphasises deep learning and understanding by allowing learners to be active rather than passive listeners. Mind mapping is also one of the instructional approaches capable of encouraging creative thinking, ability, and long-term memory in students. Teachers can make use of mind mapping to improve learning, note-taking, problem-solving, and retention (Yusuf, 2012). According to Yusuf (2012), mind mapping may also improve critical thinking in students.

Critical thinking is a term used to describe deliberate and self-contained judgment. According to Paul (2012), critical thinking is a disciplined intellectual process that involves actively and expertly conceptualizing, applying, analyzing, synthesizing, or evaluating knowledge. Halpern (2018) defined critical thinking as goal-directed, reasoned, and deliberate thinking that is used to solve issues, draw inferences, estimate probabilities, and make decisions. According to Paul and Elder (2014), critical thinking is "that approach to considering any subject, substance, or problem—in which the thinker enhances the quality of his or her thinking by deftly seizing control of the structures inherent in thinking and imposing intellectual norms upon them. "Critical thinking (CT) is

one of the most important components of thinking abilities in academia since it allows a person to examine, assess, explain, and reorganize their thinking, lowering the danger of accepting, acting on, or thinking with a wrong belief. Ennis, (2017) stated that critical thinking has to do with Reasonable reflective thinking that is focused on determining what to believe or do. Singh (2014) stated that critical thinking has to do with analogy, analyzing arguments, logical analysis, interpretation, and the recognition of assumptions, deductions, and inferences. Wallace (2002) believes that all students can think but that their thinking abilities can only be improved with the use of innovative teaching methods.

According to the research, mind mapping can be an effective teaching approach for improving cognitive development (Al-Swalha, 2021; Abbas, Eldin & Elsayed,2018; Carlson & Daniel, 2011 Katcha, Orji, Ebele, Abubakar, and Mohammed (2018) suggest that implementing mind mapping improves students' critical thinking. The majority of these studies focus on subject area such as Civic Education, basic science and Social studies, and no research on the effect of mind mapping instructional strategy on students' achievement and critical thinking in chemistry has been discovered. As a result, the investigator chose the mind mapping instructional strategy as an independent variable and academic achievement as well as critical thinking as dependent variables in the current study to cover these gaps.

Statement of the Problem

There is a growing concern about which strategy or method of teaching in our secondary schools should be able to reverse deteriorating trends in students' poor achievement in Chemistry. Some suggestions have been made regarding the identification of science teaching methods and strategies which motivate students better to learn and achieve superior results in their study of Chemistry. Research results reveal that the methods presently in use by teachers of Chemistry are the traditional, talk or lecture rather than the strategies that involve students' participation (Agwagah, 2013). Probably, the non-use of innovative methods that are problem solving oriented such as concept maps, mind maps and so on could be the main cause deteriorating students' achievement and low interest in Chemistry.

However, mind-mapping has been used as an effective strategy in enhancing students' achievement both in other subjects and outside Nigeria, and it has been reported to have produced the desired effective teaching in secondary schools such that students' achievement and critical thinking improve. To the best of the researcher's knowledge, whether this mind-mapping instructional strategy could enhance students' academic achievement and critical thinking among secondary school students in Chemistry in Delta State is yet to be empirically established. Hence, this study focuses on the effect of mind-mapping instructional strategy on senior secondary school chemistry students' academic achievement and critical thinking.

Research Questions

The following research questions guided this study

1. What is the difference in the mean achievement scores of students taught Chemistry using to mind-mapping strategy and those taught using the conventional method?
2. What is the difference between the mean achievement scores of male and female students taught Chemistry using mind-mapping instructional strategy?
3. What is the interaction effect of instructional strategies (mind mapping instructional strategy, conventional lecture method) and sex on students' academic achievement in Chemistry?
4. What is the difference in the mean critical thinking scores of students taught Chemistry using to mind-mapping strategy and those taught using the conventional method?
5. What is the difference between the mean critical thinking scores of male and female students taught Chemistry using mind-mapping strategy?
6. What is the interaction effect of instructional strategies (mind mapping instructional strategy, conventional lecture method) and sex on students' critical thinking in Chemistry?

Hypotheses

The following null hypothecs were tested at 0.05 level of significant

1. There is no significant difference in the mean achievement scores of students taught Chemistry using to mind-mapping strategy and those taught using the conventional method.
2. There is no significant difference between the mean achievement scores of male and female students taught Chemistry using mind-mapping instructional strategy.
3. There is no significant interaction effect of instructional strategies (mind mapping instructional strategy, conventional lecture method) and sex on students' academic achievement in Chemistry.

4. There is no significant difference in the mean critical thinking scores of students taught Chemistry using to mind-mapping strategy and those taught using the conventional method.
5. There is no significant difference between the mean critical thinking scores of male and female students taught Chemistry using mind-mapping strategy.
6. There is no significant interaction effect of instructional strategies (mind mapping instructional strategy, conventional lecture method) and sex on students' critical thinking in Chemistry

Purpose of the Study

The purpose of this study was to determine the effect of mind-mapping instructional strategy on senior secondary school chemistry students' academic achievement and critical thinking. The study specifically:

1. determined in the difference in the mean achievement scores of students taught Chemistry using to mind-mapping strategy and those taught using the conventional method
2. examined difference between the mean achievement scor+es of male and female students taught Chemistry using mind-mapping instructional strategy.
3. explore the interaction effect of instructional strategies (mind mapping instructional strategy, conventional lecture method) and sex on students' academic achievement in Chemistry
4. find out the difference in the mean critical thinking scores of students taught Chemistry using to mind-mapping strategy and those taught using the conventional method?
5. investigated difference between the mean critical thinking scores of male and female students taught Chemistry using mind-mapping strategy?
6. explored interaction effect of instructional strategies (mind mapping instructional strategy, conventional lecture method) and sex on students' critical thinking in Chemistry?

Significance of the Study

This study may be of immense benefit to teachers, students, curriculum planner, Ministry of Education, school administrators and researchers.

This research is likely to benefit instructors since it will raise their awareness of the effectiveness of mind mapping in the teaching and learning of Chemistry. It may persuade currently employed teachers to recognise the necessity for in-service training in order to effectively teach Chemistry using these methods. The study's findings may be beneficial to instructors since they will allow them to properly pick between two instructional strategies, one of which will increase teachers' output more than the other.

The study's conclusions will be used as a guide by curriculum designers to help them prepare for the implementation of a thorough and effective chemistry curriculum. The student may gain from the research. Student achievement may be improved since any instructor who comes across the research must have benefited from how one of the two tactics can boost teacher effectiveness. To encourage teachers to keep their knowledge and skills current through seminars, workshops, and conferences, school administrators may want to encourage instructors to use the study to better grasp the value of this instructional technique. The findings of the study, as well as the recommendations made in the study, may be valuable to future researchers in the field of chemistry. The pertinent information presented in this study may become a source of reference for them, and it may inspire a new strategy for researching topics impacting test score accomplishment in Chemistry in particular, and other disciplines in general, in the educational system.

Scope and Delimitation of the Study

This study determined the effect of mind-mapping instructional strategy on senior secondary school chemistry students' academic achievement and critical thinking. The study covered instructional strategies at two treatment levels such as mind-mapping (experimental) and conventional instructional strategy (control) in relation to sex and students critical thinking. The study covered all the senior Secondary Schools II students in Delta State. However, the study was restricted to two secondary schools in Delta State and SSI, and students from private secondary schools were excluded from this study.

Research Method and Procedure

The design adopted for this study was quasi-experimental using a 2 x2 factorial design. The population of this study comprises a total of 29,409 SS II students offering Chemistry in all the government-owned secondary schools in Delta State for the 2021/2022 session. A sample of 48 SS2 students was drawn from two secondary schools in Delta State. The schools were chosen using the purposive non-randomized sampling technique. The Chemistry Achievement Test (CAT) and questionnaire were the tools employed in the study. There are two sections to the CAT. Instructions on the student's biodata were in Section A. Four different concepts or topics are covered by the 25 multiple-objective test items in Section B, which have option letters from A to D. The questionnaire was titled "Students' Critical Thinking Scale" (SCTS). The Students' Critical Thinking Scale, which has 21 items, was slightly modified from Okan (2012). Section A was made to gather personal information on gender (male and female). The respondents were asked to rate a series of four-point statements using close-ended options such as "Strongly Agree" (4 points),

"Agree" (3 points), "Disagree" (2 points), and "Strongly Disagree" (1 point). For each of the experimental groups, four lesson plans that were modified from NERDC (2012) were employed. The lesson plans that were created covered four subjects that were chosen from the Delta State secondary schools' uniform scheme of work. The researcher enlisted the aid of two specialists from Delta State University, Abraka, and the project supervisor to validate the Chemistry Achievement Test (CAT). The science department provided one expert, and measurement and evaluation provided the second expert. CAT's content validity was checked using the specs table. Each concept's material was taken from the Delta State SS II uniform scheme of work. The two specialists reviewed the lesson plans. The degree to which the lesson plans complied with the two teaching approaches' theoretical underpinnings was reviewed by the experts. The lesson plans were additionally reviewed by a qualified chemistry teacher. The feedback from the experts and instructors was used to improve the lesson plan.

The researcher determined the reliability of the CAT by administering the instrument to 40 SS II students from two secondary schools in Benin City, Edo State. The instrument's reliability was calculated using Kuder-Richardson formula 21, which was used to determine the reliability index, which produced a result of 87. The approach was deemed appropriate because the Chemistry Achievement Exam (CAT) test components are multiple-choice achievement tests with dichotomous scoring (correct or wrong). Cronbach's alpha was used to assess the SCT's reliability, and a reliability coefficient of 0.89 was found. Given that the SCT's reliability calculation was based on a four-point scale, Cronbach's alpha was deemed appropriate. The reliability test was done in order to determine the internal consistency of CAT and SCT.

On the first day of the experiment, pretests utilising the Chemistry Achievement Test were given to the groups after they had been divided into each treatment group. The pretest was given to assess prior knowledge of the subjects covered by the test as well as to determine the similarity between the experiment and control groups. The researcher's lesson plans for each group were used by the regular Chemistry teacher in each secondary school to conduct the actual teaching for six weeks. Each secondary school conducted a post-test on the students after the teacher had finished teaching, using the identical Chemistry Achievement Test (CAT) as the pretest. Using the mean scores and standard deviations of the scores, the research questions were addressed. T-test analysis and the Analysis of Covariance (ANCOVA) were used to test hypotheses at significance levels of 0.05.

RESULTS AND DISCUSSION

Research Question One

What is the difference in the mean achievement scores of students taught Chemistry using mind-mapping instructional strategy and those taught using the conventional method?

Table 1: Mean and Standard Deviation (SD) Comparison of the Pretest and Post Test achievement scores of students taught Chemistry using to mind-mapping strategy and those taught using the conventional method

Instructional methods	N	Pretest		Posttest		Mean Difference
		Mean	SD	Mean	SD	
Mind Mapping Instructional strategy	23	8.09	.67	22.61	2.19	14.52
Conventional Method	25	7.92	.49	12.00	4.56	4.08
Total	48					

In table 1, the pretest and posttest mean scores for the group using the mind mapping instructional strategy are 8.09 and 22.61, respectively, with standard deviation scores of.67 and 2.19. Additionally, the control group's pretest and posttest means were 7.92 and 12.00, respectively, with standard deviations of.49 and 4.56. For the mind mapping instructional strategy, there was a 14.52 marginal difference between the pretest and posttest mean achievement score, compared to a 4.08 mean difference for the control group.

Research Question Two

What is the difference between the mean achievement scores of male and female students taught Chemistry using mind-mapping strategy?

Sex	N	Pretest		Post-test		Mean Difference
		Mean	SD	Mean	SD	
Males	14	8.00	.68	23.00	1.62	15.00
Females	9	8.22	.67	22.00	2.87	13.77

Total	23

According to Table 2, the pretest and posttest mean achievement scores of male students taught chemistry using the mind mapping instructional strategy were 8.00 and 23.00, respectively, with standard deviation scores of.68 and 1.62. Furthermore, the pretest and posttest mean scores for female students taught chemistry using the mind-mapping instructional strategy were 8.22 and 22.00, respectively, with standard deviation scores of.67 and 2.87. The difference between the mean achievement score for the boys and girls between the pretest and posttest was 15.0, while it was 13.77 for the females.

Research Question Three

What is the interaction effect of instructional strategies (mind mapping instructional strategy, conventional lecture method) and sex on students' academic achievement in Chemistry?

Table 3: Mean and Standard Deviation(SD) on Interaction Effect of Mind Mapping Instructional Strategy, Conventional Lecture Method and Sex On Students' Academic Achievement in Chemistry

			Posttest		Pretest		
Methods	SEX	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean difference
Mind Mapping Instructional Strategy	Males	14	23.00	1.62	8.00	.68	15.00
	Females	9	22.00	2.87	8.22	.67	13.78
	Total	23	22.61	2.19	8.09	.67	14.52
Conventional Lecture Method	Males	13	13.38	4.46	7.92	.277	5.46
	Females	12	10.50	4.36	7.92	.67	2.58
	Total	25	12.00	4.56	7.92	.49	4.08
Total	Males	27	18.37	5.87	7.96	.52	10.41
	Females	21	15.43	6.91	8.05	.67	7.38
	Total	48	17.08	6.45	8.00	.58	9.08

The interaction between instructional strategies (conventional lecture and mind mapping) and sexuality on students' academic achievement in Chemistry is shown in Table 3. According to the results, the male students who were taught chemistry using the mind mapping instructional technique had pretest means of 8.00 with 0.68 standard deviations and posttest means of 23.00 with 1.62 standard deviations. For the male students who were taught using the mind mapping instructional technique, the difference between the pretest and posttest mean scores was 15.00. A pretest means of 8.22 with a standard deviation of 0.67 and a posttest mean of 22.00 with a standard deviation of 2.87 were recorded for the female students who were taught chemistry utilising the mind mapping instructional strategy. The difference between the pretest and posttest means for female group was 13.78.

Table 3 also reveals that the mean pretest and average posttest scores for the male students who were instructed in chemistry using the traditional lecture method were 7.92 and 2.77, respectively. For the male group, the difference between the pretest and posttest averages was 5.46. The pretest means for the female students taking the traditional lecture-based chemistry was 7.92, with a standard deviation of 0.67, while the posttest mean was 10.50, with a standard deviation of 7.92. For the female group, there was a 2.58 difference between the pretest and posttest means.

Regardless of the instructional method used, the overall mean score for male and female students on the pretest and posttest was 7.96 and 8.05, 18.37 and 15.43, respectively, with a mean difference of 10.41 and 7.38 in favour of male students. This suggests that chemistry student achievement may be slightly impacted by the relationship between instructional strategies and sex.

Research Question Four

What is the difference in the mean critical thinking scores of students taught Chemistry using to mind-mapping strategy and those taught using the conventional method?

Table 4: Mean and Standard Deviation Comparing the Critical Thinking Scores of Students taught Chemistry using Mind-Mapping Strategy and Those taught using the Conventional Method

	Methods	N	Mean	Std. Deviation	Mean difference
Critical thinking score	Mind mapping instructional strategy	23	61.48	5.95	9.48
	Conventional lecture method	25	51.00	10.73	

Table 4 reveals the mean and standard deviation of critical thinking scores of students taught chemistry using a mind-mapping strategy and those taught using the conventional method. It can be seen that the mean critical thinking score of students taught chemistry using a mind-mapping strategy is 61.48 with a standard deviation of 5.95 and those taught using the conventional method is 51.00 with a standard deviation of 10.73. This shows that the mean score of students taught using the mind mapping instructional strategy is higher than those taught using the conventional lecture method, with a mean difference of 9.48.

Research Question Five

What is the difference between the mean critical thinking scores of male and female students taught Chemistry using mind-mapping strategy?

Table 5: Mean and Standard Deviation Analysis mean critical thinking scores of male and female students taught Chemistry using mind-mapping strategy

	Sex	N	Mean	Std. Deviation	Mean difference
Critical Thinking	Males	14	60.64	6.81	2.14
	Females	9	62.78	4.35	

Table 5 reveals the mean and standard deviation of critical thinking scores of male and female students taught chemistry using a mind-mapping instructional strategy. It can be seen that the mean critical thinking score of males is 60.64 with a standard deviation of 6.81 and that of their female counterparts is 62.78 with a standard deviation of 4.35. This shows that the mean score of the males is slightly higher than that of the females, with a mean difference of 2.13.

Research Question Six

Table 6: Descriptive statistics showing interaction Effect of Mind Mapping Instructional Strategy, Conventional Lecture Method and Sex on Students' Critical Thinking in Chemistry

Treatment Methods	Sex	N	Mean	Std. Deviation	Mean Difference
Mind Mapping Instructional Strategy	Males	14	60.64	6.81	
	Female	9	62.78	4.35	2.46
	Total	23	61.48	5.95	
Conventional Lecture Method	Males	13	51.38	8.64	
	Female	12	50.58	13.01	0.80
	Total	25	51.00	10.73	

Table 6 reveals the mean and standard deviation of critical thinking score for male and female students taught using mind mapping instructional strategy and those taught using Conventional Lecture Method. The critical thinking mean scores and standard deviation for males and females taught using the mind mapping instructional strategy are 60.64 and 62.78, 6.81 and 4.35, respectively. Whereas the critical thinking mean scores and standard deviation for males and females taught using Conventional Lecture Method are 51.3846 and 50.5833, 8.63654 and 13.01369, respectively.

Hypothesis One

There is no significance difference in the mean achievement scores of students taught Chemistry using to mind-mapping instructional strategy and those taught using the conventional method.

Table 7: t-test comparison of the pretest and post-test mean achievement scores of students taught Chemistry using to mind-mapping instructional strategy and those taught using the conventional method

	Treatment Method	N	Mean	Std. Deviation	Df	t-cal.	t-crit.	Level of sign.
Pretest	Mind mapping instructional strategy	23	8.09	.67	46	.99^{ns}	2.00^{ns}	0.05
	Conventional Method	25	7.92	.49				
Posttest	Mind mapping instructional strategy	23	22.61	2.19	46	10.12^{s}	2.00^{s}	0.05
	Conventional Method	25	12.00	4.56				

Ns= not significant; s= significant

Table 7 reveals the summary of the t-test analysis of the pretest and post-test mean achievement scores of students taught chemistry using the mind mapping instructional strategy and those taught using the conventional method. The table shows that in the pretest, the mind mapping instructional strategy and conventional method groups' mean scores are 8.09 and 22.61, with standard deviation scores of 6.68 and 2.19, respectively. This gives a calculated t-value of.99 and a critical t-value of 1.67. The t-value calculated is less than the t-critical value of 1.67 at an alpha level of 0.05. This indicates that there is no significant difference in the mean achievement scores of students taught chemistry using the mind mapping instructional strategy and those taught using the conventional method in the pretest. This means that the two groups were marginally equivalent before the treatment began.

However, in the post-test analysis, the calculated t-value of 10.12 is greater than the critical t-value of 1.67. (t = 10.12, df = 46, alpha level = 0.05). The null hypothesis was therefore rejected. This implies that there is a significant difference in the mean achievement scores of students taught chemistry using the mind mapping instructional strategy and those taught using the conventional method. Based on this, it could be concluded that the use of mind mapping as an instructional strategy enhanced chemistry students' academic achievement better than the conventional method.

Hypothesis Two

There is no significance difference in the mean achievement scores of male and female students taught Chemistry using mind-mapping strategy.

Table 8: t-test comparison of the pretest and post-test mean achievement scores of Male and female students taught Chemistry using to mind-mapping instructional strategy

	Sex	N	Mean	Std. Deviation	Df	t-cal.	t-crit.	Level of sign.
Pretest	Male	14	8.00	.68	21	.77^{ns}	2.08^{ns}	0.05
	Female	9	8.22	.67				
Posttest	Male	14	23.00	1.62	21	1.07^{ns}	2.08^{s}	0.05
	Female	9	22.00	2.87				

Ns= not significant

Table 7 reveals the summary of the t-test analysis of the pretest and post-test mean achievement scores of students taught chemistry using the mind mapping instructional strategy and those taught using the conventional method. The table shows that in the pretest, the mind mapping instructional strategy and conventional method groups' mean scores are 8.09 and 22.61, with standard deviation scores of 6.68 and 2.19, respectively. This gives a calculated t-value of.99 and a critical t-value of 1.67. The t-value calculated is less than the t-critical value of 1.67 at an alpha level of 0.05. This indicates that there is no significant difference in the mean achievement scores of students taught chemistry using the mind mapping instructional strategy and those taught using the conventional method in the pretest. This means that the two groups were marginally equivalent before the treatment began.However, in the post-test analysis, the calculated t-value of 10.12 is greater than the critical t-value of 1.67. (t = 10.12, df = 46, alpha level = 0.05). The null hypothesis was therefore rejected. This implies that there is a significant difference in the mean achievement scores of students taught chemistry using the mind mapping instructional strategy and those taught using the conventional method. Based on this, it could be concluded that the use of mind mapping as an instructional strategy enhanced chemistry students' academic achievement better than the conventional method.

Hypothesis Three

There is no significant interaction effect of instructional strategies (mind mapping instructional strategy, conventional lecture method) and sex on students' academic achievement in Chemistry.

Table 9: Summary of ANCOVA of the Interaction Effects of Instructional Methods (Mind Mapping Instructional Strategy, Conventional Lecture Method) and Sex on Students' Academic Achievement in Chemistry

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1405.59[a]	3	468.53	37.61	.00
Intercept	13842.31	1	13842.31	1111.27	.00
Instructional Methods * Sex	1405.59	3	468.53	37.61	.00
Error	548.08	44	12.46		
Total	15962.00	48			
Corrected Total	1953.67	47			

a. R Squared = .719 (Adjusted R Squared = .700)

Table 9 revealed the summary of ANCOVA of the interaction effects of instructional methods (mind mapping instructional strategy, conventional lecture method) and sex on students' academic achievement in Chemistry. The computed F-ratio, i.e., F (3, 44) is 37.61 with a p-value of 0.00. Testing the null hypothesis at an alpha level of 0.05, the p-value of 0.00 was less than the alpha level of 0.05, hence the null hypothesis was rejected. This implies that there is a significant interaction effect between instructional methods (mind mapping instructional strategy, conventional lecture method) and sex on students' academic achievement in Chemistry. Figure 1 depicts the nature of interaction graphically. In the graph below, there is a type of interaction called "ordinal interaction." This means that there is no visible crossing of the lines connecting the mean achievement scores.

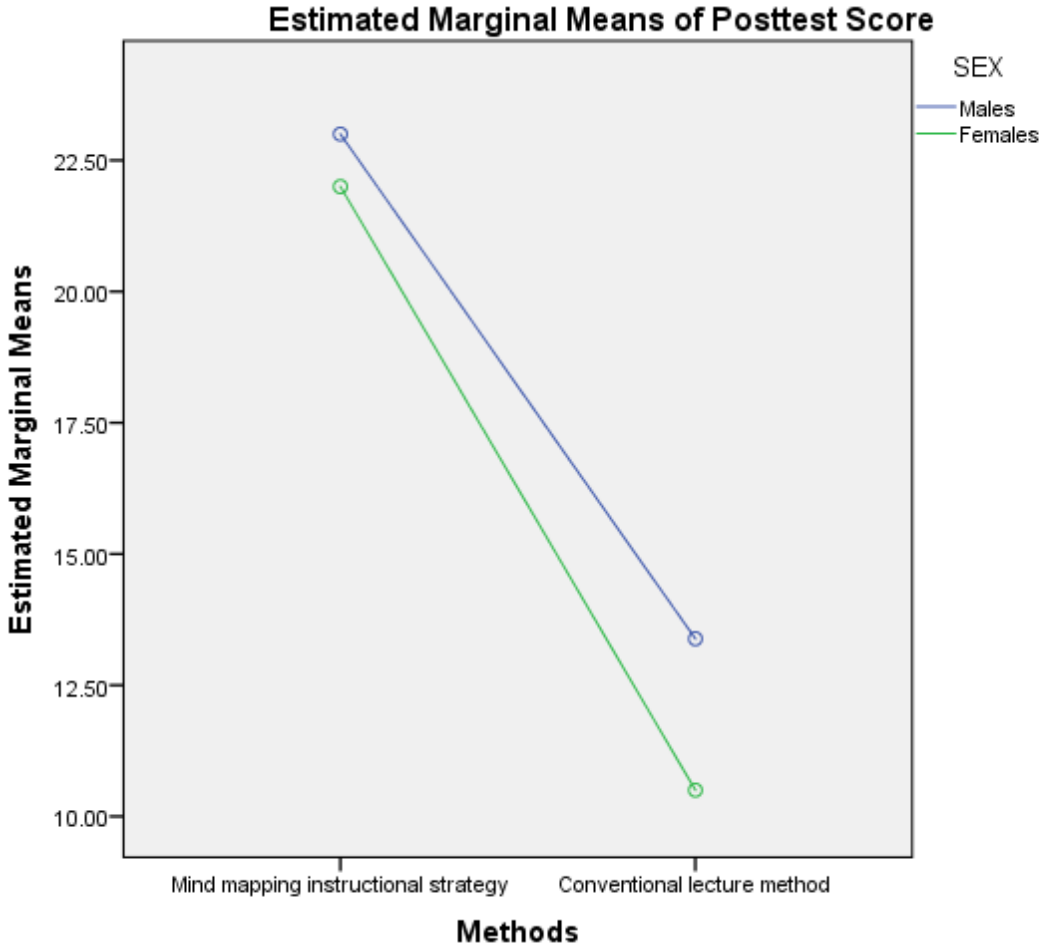


Figure 1: interaction effect of instructional strategies (mind mapping instructional strategy, conventional lecture method) and sex on students' academic achievement

Hypothesis Four

There is no significant difference in the mean critical thinking scores of students taught Chemistry using mind-mapping strategy and those taught using the conventional metho**d**

Table 10: t-test Comparison of the Critical Thinking Scores of Students taught Chemistry using Mind-Mapping Strategy and those taught using the Conventional Method

	Variables	N	Mean	Std. Deviation	df	t-cal.	t-crit.	Level of sign.
Critical thinking score	Mind mapping instructional strategy	23	61.48	5.95	46	4.13[s]	2.00	0.05
	Conventional lecture method	25	51.00	10.73				

Table 10 shows the students' independent sample t-test comparison of the critical thinking scores of students taught Chemistry using the Mind-Mapping Strategy and those taught using the Conventional Method. It shows that the difference in mean scores between these sets of students, as observed in table 9, was significant. This is because the t-value (4.133) obtained is greater than the critical t-value (2.00) at the 0.05 level of significance. With this, the null hypothesis, which states that there is no significant difference between the critical thinking scores of students taught chemistry using mind-mapping instructional strategy and those taught using the conventional method, was rejected. This implies that there is a significant difference between the critical thinking scores of students taught chemistry using a mind-mapping instructional strategy and those taught using the conventional method.

Hypothesis Five

There is no significant difference in the mean critical thinking scores of male and female students taught Chemistry using mind-mapping strategy.

Table 11: independent t-test comparison of the critical thinking scores of male and female students taught Chemistry using mind-mapping strategy

	Sex	N	Mean	Std. Deviation	df	t-cal.	t-cri.t	Level of sign.
Critical Thinking	Males	14	60.64	6.81	21	-.83	2.08	0.05
	Females	9	62.78	4.35				

Table 11 shows the students' independent sample t-test comparison of the critical thinking scores of male and female students taught Chemistry using mind-mapping strategy. It shows that the difference in mean scores between these sets of students, as observed in Table 5, was not significant. This is because the t-value (-.83) obtained is less than the critical t-value (2.08) at the 0.05 level of significance. With this, the null hypothesis, which states that there is no significant difference between critical thinking scores of male and female students taught Chemistry using mind-mapping strategy was accepted. This implies that the use of a mind-mapping instructional strategy enhanced the achievement of male and female students in chemistry in an equal manner.

Hypothesis Six

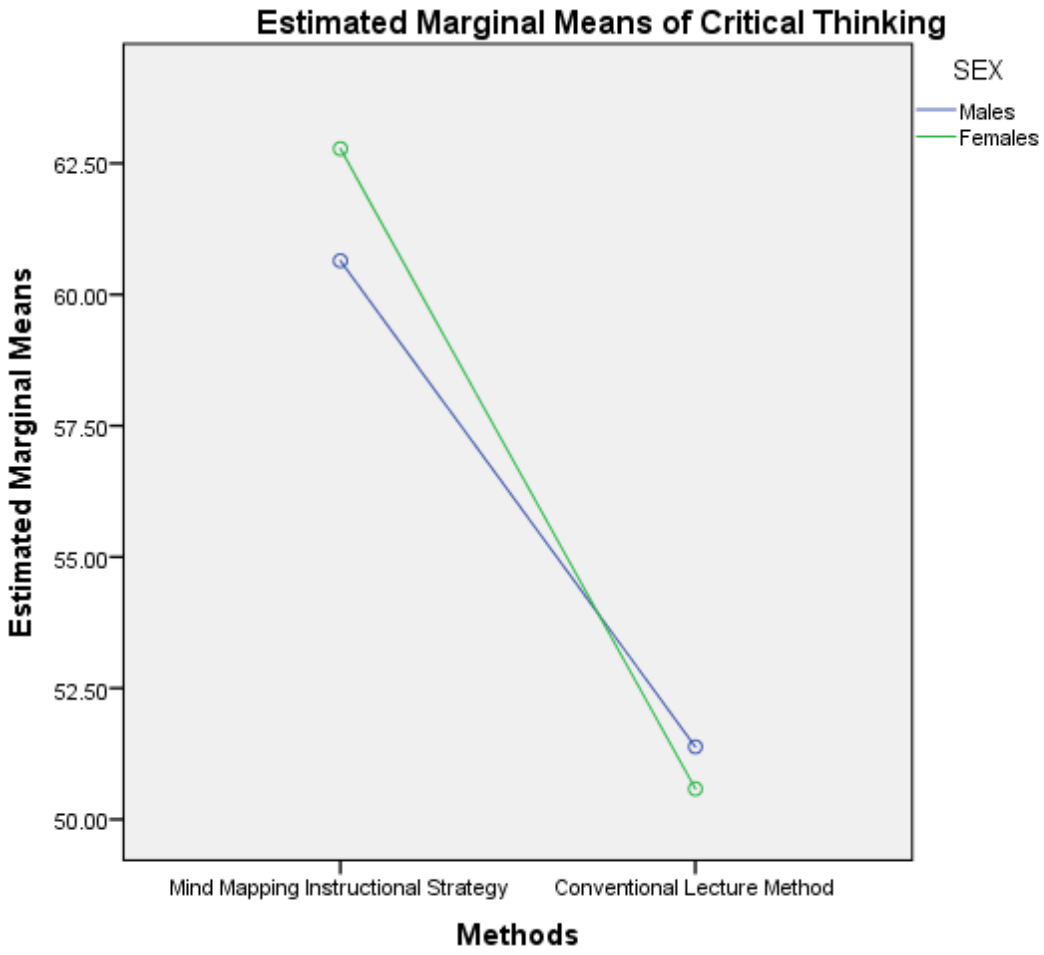
There is no significant interaction effect of instructional strategies (mind mapping instructional strategy, conventional lecture method) and sex on students' critical thinking in Chemistry.

Table 12 Analysis of Variance (ANOVA) statistics showing interaction effect of instructional methods (mind mapping instructional strategy, conventional lecture method) and sex on students' Critical Thinking in Chemistry.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1344.22[a]	3	448.07	5.61	.00
Intercept	148193.09	1	148193.09	1856.23	.00
instructional methods * Sex	1344.22	3	448.07	5.61	.00
Error	3512.76	44	79.84		
Total	155497.00	48			
Corrected Total	4856.98	47			

a. R Squared = .277 (Adjusted R Squared = .227)

Table 12 revealed the summary of ANCOVA of the interaction effects of instructional methods (mind mapping instructional strategy, conventional lecture method) and sex on students' critical thinking in Chemistry. The computed F-ratio, i.e., F (3, 44) is 5.61 with a p-value of 0.00. Testing the null hypothesis at an alpha level of 0.05, the p-value of 0.00 was less than the alpha level of 0.05, hence the null hypothesis was rejected. This implies that there is a significant interaction effect between instructional methods (mind mapping instructional strategy, conventional lecture method) and sex on students' critical thinking in Chemistry. Figure 1 depicts the nature of interaction graphically. In the graph below, there is a type of interaction called "disordinal interaction." This means that there is a visible crossing of the lines connecting the mean achievement scores.



Discussion of Results

The study investigated the effects of a mind-mapping instructional strategy on senior secondary school chemistry students' academic achievement and critical thinking. Six hypotheses were formulated and analysed. Analysis of the first hypothesis shows that there is a significant difference in the mean achievement scores of students taught chemistry using the mind mapping instructional strategy and those taught using the conventional method. The possible reasoning for this finding could be that the use of mind-mapping instructional strategy enhanced chemistry students' academic achievement better than the conventional method. This finding agrees with that of Akanbi, Abdulrasaq, Olayinka, Omosewo, Mohammed, and Ridwan Enuwa (2021), which revealed that there was a significant effect of the mind-mapping instructional strategy achievement of senior secondary school students. The finding also aligned with Nacilla and Dolotallas (2019), who found that there was a significant difference in the students' pretest and posttest scores in Biology when exposed to Mind Mapping as a learning strategy and the Lecture Method. The finding, however, disagrees with Wickramasinghe (2007), who did not find significant statistical differences between the use of mind mapping and the conventional method for medical students.

Analysis of the second hypothesis shows that there is no significant difference in the mean achievement scores of male and female students taught chemistry using a mind-mapping instructional strategy. The possible explanation for this finding is that the use of a mind-mapping instructional strategy enhanced the achievement of male and female students in chemistry in an equal manner.

This finding agrees with Alao and Abubakar (2011) that there is no significant difference between male and female students' performance in physics. The finding equally aligns with Amedu (2015), who revealed that gender has no influence on students' academic performance in senior secondary schools. This finding, however, disagrees with Bawaneh (2018), who revealed that there was a significant difference between students' genders on immediate achievement.

Analysis of the third hypothesis shows that there is a significant interaction effect between instructional methods (mind mapping instructional strategy, conventional lecture method) and sex on students' academic achievement in Chemistry. The possible explanation for this finding could be that instructional strategies and sex could impact the academic achievement of students. This finding aligns with Anaekwe (1997), who reported a significant effect of students' interaction patterns on students' achievement. The finding, however, contradicts that of Gagi, Skuban, Radulovi, Stojanovi, & Gaji, 2019 who show that there is no statistically significant interaction effect of the mind mapping instructional strategy and gender on students' performances in physics.

Analysis of the fourth hypothesis shows that there is a significant difference between the critical thinking scores of students taught chemistry using a mind-mapping instructional strategy and those taught using the conventional method. This finding could be due to the fact that mind mapping as an instructional strategy facilitates critical thinking compared to the conventional method. This finding aligns with Yusuf, (2012) who found that mind mapping enhances the development of certain skills in learners such as thinking skills, reasoning skills, and ability to make decision, taking action, information gathering and critical thinking. This finding also corroborated that of Antoni, Zipp, Olson, and Cahill (2010), who stated that using mind mapping as a note-taking strategy facilitates critical thinking. The finding also agrees with Arulselvi (2017), who reveals that mind mapping encourages the learner to think critically.

Analysis of the fifth hypothesis shows that there is no significant difference between the critical thinking scores of male and female students taught chemistry using a mind-mapping strategy. This implies that the use of a mind-mapping instructional strategy enhanced the achievement of male and female students in chemistry in an equal manner. This finding is consistent with Rima (2019), who found no significant difference in critical thinking scores between male and female students who used the mind-mapping strategy. Thegrees with Ahmad and Duskri (2018), who showed that the critical thinking skills of female students were slightly better than those of male students.

Analysis of the sixth hypothesis shows that there is a significant interaction effect between instructional methods (mind mapping instructional strategy, conventional lecture method) and sex on students' critical thinking in Chemistry. This finding indicates that instructional strategies and sex have an impact on students' critical thinking in chemistry.

Conclusion

In line with the findings of this study, it could be concluded that the use of mind mapping instructional strategy enhanced chemistry students' academic achievement better than the conventional method. It can also be concluded that the use of mind mapping instructional strategy enhanced chemistry students' critical thinking better than the conventional method. Furthermore, the use of a mind-mapping instructional strategy enhanced the achievement and critical thinking of male and female students in chemistry in an equal manner.

Contributions to Knowledge

This study has contributed to knowledge in the following ways:udy has established that the use of mind mapping as an instructional strategy enhanced chemistry students' academic achievement better than the conventional method.

1. The study also affirmed that the use of mind mapping instructional strategy enhanced chemistry students' critical thinking better than the conventional method.
2. The study has again established that the use of a mind-mapping instructional strategy enhanced the achievement and critical thinking of male and female students in chemistry in an equal manner.
3. The study has established that there is an interaction effect of instructional methods and sex on students' academic achievement in chemistry.
4. The study has established that there is a disordinal interaction effect of instructional methods and sex on students' critical thinking in chemistry.

Recommendations

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

1. In the classroom, chemistry teachers should aim to introduce students to mind mapping as an instructional method that promotes and encourages active engagement in learning, learning by doing, and learning by experience.

2. Curriculum planners should include a mind mapping instructional strategy in their plans since it will assist students in improving their academic achievement in chemistry.
3. The use of a mind-mapping instructional strategy had no effect on male or female student achievement in Chemistry. As a result, teachers should make chemistry teaching and learning gender-neutral.
4. Because the mind mapping instructional strategy proved more effective in teaching chemistry and improving student academic achievement, ministries of education should ensure that textbook publishers include the mind mapping instructional strategy in secondary school instructional techniques.
5. Regular workshops, seminars, and symposia on chemistry curriculum topics and concepts should be organized from time to time by universities for chemistry instructors in secondary schools so that they are exposed to novel teaching methodologies. In such situations, instructional tools such as mind mapping could be used.

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