INTEGRATING SELF-REGULATED LEARNING AND MIND MAPS INTO THE SENIOR SECONDARY SCHOOL PHYSICS CURRICULUM TO ENHANCE STUDENTS' DELAYED POSTTEST ACHIEVEMENT IN DELTA STATE.

Abstract

The study investigatedintegrating self-regulated learning and mind maps into the senior secondary school physics curriculum to enhance students' delayed posttest achievement in Delta State. The design adopted for this study wasquasi-experimental, specifically the pre-test, post-test, delayed post-test, non-randomized 3 X 2 X 3 factorial planned variation design. The population for this study consisted of 39,904 SS II physics students in Delta State. 322 (169 male and153 female) SS II physics students from 6 intact classes from 6 co-educational secondary schools in the three Senatorial Districts of Delta State formed the sample size for the study. The instrument, Physics Achievement Test (PAT), which was face and content validated with a reliability of 0.86, established using Kuder-Richardson's formula 21 (KR-21), was used for data collection. Research questions raised were answered using mean and standard deviation, while hypotheses formulated were tested using Analysis of Covariance (ANCOVA), paired sample, and independent t-test at 0.05 significance level. The study found that; there is asignificant difference in the delayed posttest mean achievement scores of students taught physics using self-regulated learning, mind maps, and lecture methods, there was no statistically significant difference between the delayed post-test mean achievement (retention) scores of male and female students taught physics using the self-regulated learning and mind map instructional strategies, and there is no statistically significant interaction effect between instructional methods and gender. It was recommended that the mind map instructional strategy should be integrated into the teaching of the physics curriculum concepts at the senior secondary school level of education for enhanced achievement and retention of students in physics.

Keywords: Self-regulated learning, mind maps, *instructional strategies,* delayed posttest achievement, gender.

Introduction

One could argue that education is an essential tool for sustainable national and human development. It is a methodical process of instruction and learning that results in a person's perception being permanently altered (Ovuworie, Ajaja, & Kpangban, 2024). The study of matter, energy, motion, force, space, time, and the basic laws governing their interactions in the natural world is known as physics. It uses measurement, experimentation, observation, and mathematical modeling to try to explain natural phenomena. It is one of the fundamental science courses taught in Nigerian senior secondary schools. It plays a crucial role in the secondary school curriculum because it allows students to use the scientific knowledge and abilities they have learned to create and develop pertinent scientific instruments.The International Union of Pure and Applied Physics (IUPAP, 1999) defined physics as the scientific study of matter and energy and their interactions with each other, which plays a key role in the future process of mankind.

Physics is the cornerstone of technological advancement because virtually all modern technologies are built upon its principles. In order to produce competent engineers, scientists, instructors, researchers, and other professionals, physics is a crucial subject (Akanbi, Olayinka, Omosewo, and Mohammed, 2021). Many scientific disciplines, such as chemistry, engineering, astronomy, environmental science, and even aspects of biology, are rooted in physical principles. Concepts like energy, force, electricity, and waves are essential for understanding everyday occurrences and natural processes. Without physics, learners would lack the basic scientific framework needed to interpret and explain both simple and complex phenomena in the environment.Innovations such as electricity generation and transmission, telecommunications, computers, medical imaging equipment (e.g., X-rays and MRI), renewable energy technologies, transportation systems, and space exploration are direct applications of physics concepts. However, despite the glaring importance of the physics curriculum in our everyday lives, it has been observed that a lot of students still perceive physics to be difficult and demanding and are really not motivated to learn it adequately. This has led to the persistent poor immediate posttest and delayed posttest achievement scores of students in the subject in internal and particularly external examinations, like the West Africa Senior School Certificate Examination (WASSCE). Several reasonshave been identified by researchers(Chiemeke& Dike, 2019; Ugwu, Fagbenro& Akano, 2019; Macmillan & Gana, 2019) as factors that are contributing to the poor and fluctuating students' physics achievement.Students' negative attitudes toward physics, a lack of desire, and a teaching and learning environment with inadequate resources are some of the explanations offered for the low achievement in physics.Furthermore, poor and fluctuating academicachievements in physics could be attributed to the teacher's strategy, which is considered a criticalfactor (Oladejo, Olosunde, Ojebisi, & Isola, 2011).

Physics, like any other science subject, can be taught using a variety of instructional strategies. However, the lecture method remains the predominant instructional method in most Nigerian secondary schools. Given its teacher-centered nature, the lecture method is often considered unsuitable for teaching activity-oriented subjects such as physics. It encourages rote learning rather than meaningful understanding, as students are largely passive recipients of information (Ovuworie, Abamba, &Esiekpe, 2025). The selection of the most suitable teaching strategy is a basic condition for a successful teaching/learning process. Teaching science subjects requires more understanding and conceptual linkage of various scientific representations. Anis-worth (2016) opined that teaching/learning techniques must provide necessary provisions for students' active engagement with explanatory ideas, theories, and evidence to enable the connection of scientific concepts to real-world purposes and practices.In order to assuage students' low achievements in physics and ensure the attainment of the objectives of the physics curriculum, teaching methods or instructional strategies that are learner-centered, in line with the principles of learning by doing, and promote students' participation in the construction and organization of knowledge must be adopted. Activity-based teaching methodsprovide students with a variety of activities, which include presenting physics concepts or ideas in colorful diagrams or images. This can motivate and facilitate students' learning and comprehension.Teaching methods or strategies with these attributes, amongst others, are self-regulated learning and mind maps.

Self-Regulated Learning Instructional Strategy (SRLIS) is a learner-centred instructional approach that emphasizes students' active control over their own learning processes. It involves learners deliberately planning, monitoring, and evaluating their cognitive, motivational, and behavioral activities to achieve specific learning goals. Under SRLIS, students are not passive recipients of information; rather, they take responsibility for setting learning objectives, selecting appropriate strategies, managing time and resources, seeking help when necessary, and reflecting on learning outcomes. Zimmerman (2013) asserted that a self-regulated learning strategy is the degree to which students are motivationally, metacognitively, and behaviorally active in their learning process and in accomplishing their goals. These abilities are a reflection of self-regulated learning (cognitive, metacognitive, and motivational abilities). In classroom practice, SRLIS typically unfolds in cyclical phases. First, during the planning or forethought phase, learners analyze the task, set achievable goals, activate prior knowledge, and choose suitable strategies. Second, in the performance or monitoring phase, students implement their chosen strategies while continuously checking their understanding, progress, and level of concentration. Finally, in the self-reflection or evaluation phase, learners assess their performance against set goals, reflect on the effectiveness of strategies used, and make decisions for future learning. This cyclical nature could make SRLIS particularly effective in promoting deep learning, retention, and transfer of knowledge across subjects such as Physics.

The Mind Maps Instructional Strategy (MMIS) is another learner-centered teaching approach that uses visual diagrams to organize, represent, and connect ideas around a central concept. In this strategy, key ideas radiate from a main topic in the form of branches, with each branch representing related concepts, sub-concepts, examples, or relationships. Words, symbols, colours, images, and arrows are deliberately used to stimulate both the logical and creative functions of the brain, thereby enhancing understanding, memory, and meaningful learning (Dhindsa & Anderson, 2011).The mind maps represent a non-linear learning approach that promotes creative and associative thinking by enabling learners to use key words and images arranged in interconnected, non-sequential patterns to link prior knowledge with new information.As a method of instruction, mind mapping actively engages learners in the learning process by encouraging them to generate, organize, and link concepts rather than memorize isolated facts. In classroom practice, the teacher introduces a central concept or topic, guides students to identify major ideas, and supports them in breaking these ideas into sub-ideas. Students then construct mind maps individually or collaboratively, using diagrams to show relationships among concepts. According to Wang (2019), mind maps are very beneficial in science education since they increase classroom productivity, pique students' curiosity, and help them develop their critical thinking skills.The strategy promotes critical thinking, creativity, and deeper comprehension, as learners must analyze content, determine key points, and visually represent connections among ideas, which can facilitate retention of content learned.

Delayed posttest achievement refers to retention in the study. Good academic achievement is closely dependent on students' retention of learned concepts, skills, and experiences over time. Retention refers to the ability of learners to store, recall, and apply previously learned knowledge after a period has elapsed. It also refers to the ability to recall or to recognize what has been learned or experienced over a long period of time (Ezemuoghalu, 2018). Research by Ezeoke (2021) revealed that students with high retentive ability achieve more in examinations.When students are able to retain instructional content effectively, they demonstrate better understanding, continuity of learning, and improved performance in subsequent assessments. Retention is students' level of academic performance measured sometime after instruction and the initial (immediate) posttest, rather than immediately at the end of teaching. Unlike an immediate posttest, which assesses shortterm learning or recall, a delayed posttest is administered after a specified interval (such as two weeks, four weeks, or more) to determine the extent to which learning has been retained over time.Thus, retention serves as a critical foundation upon which sustained academic achievement is built,regardless of gender.

Gender is associated with attitudes that distinguish masculine characteristics from feminine ones. In this study, it refers to the state of being male or female. It is the characteristics by means of which people define male or female. One of the variables that has been shown to have an impact on students' performance and retention in science subjects is gender. Several studies have shown unimpressive students' retention rates at the senior secondary school level in Nigeria (Achor & Imoko, 2009; Kurumeh & Onah, 2012; Ajayi & Ogbeba, 2017).The employment of inefficient instructional strategies, including lectures, has been connected to the observed low retention ability among students. Most of the time, students are unable to apply what they learn in the classroom to real-world scenarios.

It is worthy of note thata plethora of studies,mostly in other subject areas but a few in physics, carried out independently have shown that self-regulatedlearning (Achufusi-Aka & Offiah, 2010; Kaptum, 2018) and mind maps (Adodo, 2013; Ogunleye& Ojekwu, 2019) are effective for enhancing students' immediate posttest academic achievement scores. The effectiveness of these strategies on physics students' delayed posttest academic achievement, however, has not been well explored.This study, therefore, determined students' delayed posttest achievement when taught using self-regulated learning, mind maps, and lecture methods in Delta State to isolate and recommend the most effective method for students' retention.

Statement of the Problem

Even though physics is important, students' academic performance in the subject, especially on the West African Senior School Certificate Examination (WASSCE) conducted by the West African Examinations Council (WAEC), has remained persistently poor. Chief Examiners' reports have consistently indicated widespread failure, shallow conceptual understanding, inability to apply principles to problem-solving situations, and weak retention of learned concepts among candidates.One major factor identified as contributing to this unsatisfactory level of achievement is the continued reliance on inappropriate and teacher-dominated instructional strategies, such as the conventional lecture method. These approaches often emphasize rote memorization, linear presentation of content, and passive learning, with little opportunity for students to actively construct knowledge, monitor their understanding, or relate new concepts to prior knowledge. Consequently, students tend to perform poorly not only in immediate post-instruction assessments but also in delayed posttests that measure long-term retention and meaningful learning. The absence of instructional approaches that foster self-regulation, such as goal setting, self-monitoring, and self-evaluation, has limited students' ability to take responsibility for their own learning. Similarly, the underutilization of visual and non-linear learning tools such as mind maps has constrained students' capacity to integrate concepts, visualize relationships, and retain information over time.In Delta State, this problem is particularly pronounced, as many secondary school physics classrooms continue to rely on traditional teaching methods that inadequately address students' diverse learning needs and cognitive processes. The persistent students' poor achievement in WAEC physics examinations suggests that current instructional practices are insufficient for enhancing both immediate achievement and delayed posttest achievement.Thus, the problem statement for this study is, will the combined use of self-regulated learning and mind maps increase senior secondary school students' delayed posttest achievement in physics more than the lecture methodin Delta State?

Research Questions

The following research questions were raised and answered at the $p < 0.05$ level of significance:

1. How do students who were taught physics with self-regulated learning, mind maps, and the lecture method differ in their delayed posttest mean achievement scores?
2. How do male and female students who were taught physics with self-regulated learning differ in their delayed posttest mean achievement scores?
3. How do male and female students who were taught physics with mind maps differ in their delayed posttest mean achievement scores?
4. How do the methods and gender interact to affect students' delayed posttest mean achievement scores?

Hypotheses

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

H_{01}: No significant variation exists in the delayed posttest mean achievement scores of students taught physics with self-regulated learning, mind maps, and lecture methods.

H_{02}: No significant variation exists in the delayed posttest mean achievement scores of maleand female students taught physics with self-regulated learning.

H_{03}: No significant variation exists in the delayed posttest mean achievement scores of maleand female students taught physics with mind maps.

H_{04}: No significant interaction exists between methods and gender in influencing students' delayed posttest mean achievement scores.

Methodology

The research employed a quasi-experimental design, specifically a pre-test, post-test, delayed post-test, non-randomized 3 × 2 × 3 factorial planned variation design. A total of 39,904 Senior Secondary School Two (SS II) physics students comprised the study's population.The study's sample size consisted of 322 SS II physics students (169 male and 153 female) from six complete classes across six coeducational secondary schools in three senatorial districts of Delta State. Twoschools each were randomly assigned to the three groups. ExperimentalGroup 1 comprised 102 students (52 male and 50 female), Experimental Group 2 comprised 119 students (56 male and 63 female), and Experimental Group3 comprised 101 students (61 male and 40 female). The Physics Achievement Test (PAT) served as the research instrument and was subjected to face and content validationwith a reliability of 0.86, established using Kuder-Richardson's formula 21 (KR-21). It consisted of fifty (50) multiple-choice test itemsthat measured students' academic delayed posttest achievement in physics based on the six-week SSII Physicsinstructional units that were covered.Before the commencement of treatment, the research assistants in experimental groups 1 and 2 were trained on how to teach students using self-regulated learning and mind map instructional strategies, respectively. Each research assistant was trained individually for three days, and in the course of training, the researcher utilized theinstructional intervention package. The two research assistants in experimental group3 were not trained since it is the conventional method. The researcher only explained the intent of the investigation and provided the lesson plan in a lecture format on the instructional units to the teachers for usage during the treatment. A pre-test was conducted for all the groups to determine their knowledge about the topic before the exercise started. The teaching was done for 6 weeks, afterwhich the post-test was conducted for students across the groups. Two weeks after the post-test was conducted, a delayed post-test was also administered. The study's research questions were addressed by analyzing the data with mean and standard deviation, and the hypotheses were examined with t-test and Analysis of Covariance (ANCOVA).

Findings

Research Question1: How do students who were taught physics with self-regulated learning, mind maps, and the lecture method differ in their delayed posttest mean achievement scores?

Table 1:
Mean and standard deviation statistics showing how students who were taught physics with self-regulated learning, mind maps, and the lecture method differ in their delayed posttest mean achievement scores

Groups	N	Posttest $\bar{X}$	SD	D-Posttest $\bar{X}$	SD	$\bar{X}Loss$
SRLIS	102	35.62	5.91	32.16	5.89	3.46
MMIS	119	41.63	5.10	38.32	5.17	3.31
LM	101	31.98	3.83	28.46	3.89	3.52

The result from Table 1indicates that students taught withself-regulated learning instructional strategy had a mean posttest score of 35.62 (SD = 5.91), while the delayed posttest mean score decreased to 32.16 (SD = 5.89). This resulted in a mean score loss of 3.46.Students in the mind mapgroup had a posttest meanscore of 41.63 (SD = 5.10), which reduced slightly to 38.32 (SD = 5.17) atdelayed posttest with a mean loss of 3.31. For the lecture method group, the mean posttest score was 31.98 (SD = 3.83), which declined to 28.46 (SD = 3.89) at the delayed posttest with a mean loss of 3.52, which is the highest,indicating greater forgetting and weaker retention compared to the other instructional strategies.

H_{01}: No significant variation exists in the delayed posttest mean achievement scores of students taught physics with self-regulated learning, mind maps, and lecture methods.

Table 2:
Results of the ANCOVA examining the delayed posttest mean achievement scores of students taught physics with self-regulated learning, mind maps, and lecture methods

Dependent Variable: Delayed posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7776.014[a]	3	2592.005	139.564	.000
Intercept	2712.215	1	2712.215	146.037	.000
Pretest	2274.469	1	2274.469	122.467	.000
Groups	6832.287	2	3416.144	183.939	.000
Error	5905.937	318	18.572		
Total	370172.000	322			
Corrected Total	13681.950	321			

a. R-squared = .568 (Adjusted R-squared = .564)

The result from Table 2 indicates that after controlling for the pretest differences, the main effect of the methods on delayed posttest achievement was statistically significant, $F(2, 318) = 183.939$, $p< 0.05$. This result implies that significant variation exists in the delayed posttest mean achievement scores of students taught physics with self-regulated learning, mind maps, and lecture methods. Therefore, H_{01}, which states that nosignificant variation exists in the delayed posttest mean achievement scores of students taught physics with self-regulated learning, mind maps, and lecture methods, is rejected. Scheffe's post-hoc test was therefore employed to specify the direction of the difference among the three groups.

Table 3: Scheffe post-hoc multiple comparison results showing pairwise differences in physics students' delayed posttest achievement (retention) scores among the three instructional methods: SRLIS, MMIS, and LM

Scheffe

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
SRLIS	2.00	-6.1625*	.68331	.000	-7.8429	-4.4820
	3.00	3.7014*	.71085	.000	1.9532	5.4496
MMIS	1.00	6.1625*	.68331	.000	4.4820	7.8429
	3.00	9.8639*	.68512	.000	8.1790	11.5488
LM	1.00	-3.7014*	.71085	.000	-5.4496	-1.9532
	2.00	-9.8639*	.68512	.000	-11.5488	-8.1790

The Scheffe post-hoc test was conducted to determine which pairs of instructional strategies differed significantly in students' physics delayed posttest achievement scores after the treatment. For SRLIS vs. MMIS, the average score gapof –6.16 is statistically significant ($p = .000$), indicating that students taught with MMIS performed significantly better on the delayed posttest than those taught with SRLIS, while for SRLIS vs. LM, the average score gap of 3.70 is statistically significant ($p = .000$), showing that students exposed to SRLIS achieved significantly higher delayed posttest scores than those taught with lecture method. For MMIS vs. SRLIS, the positive average score gap of 6.16 ($p = .000$) indicates that MMIS significantly outperformed SRLIS in enhancing students' retention of physics concepts, while for MMIS vs. LM, the largest average score gap of 9.86 was observed here and is statistically significant ($p = .000$). This indicates that students taught with mind maps achieved substantially higher delayed posttest scores than those taught with the lecture method. For LM vs. SRLIS, the mean difference of –3.70 ($p = .000$) indicates that the lecture method resulted in significantly lower delayed posttest achievement compared to SRLIS, while for LM vs. MMIS, the average score gap of –9.86 ($p = .000$) shows that the lecture method was markedly less effective than MMIS in promoting students' retention.The Scheffe post-hoc analysis,therefore, showed that the MMISwas the most effective method, followed by SRLIS, while the LM was the least effectivein enhancing students' long-term retention of physics concepts.

Research Question 2: How do male and female students who were taught physics with self-regulated learning differ in their delayed posttest mean achievement scores?

Table 4:

Descriptive statistics of mean and standard deviation comparison of how male and female students who were taught physics with self-regulated learning differ in their delayed posttest mean achievement scores

Gender	N	$\bar{X}$D-Posttest	$\bar{X}$Diff	SD
Male	52	32.88	1.48	5.95
Female	50	31.40		5.80

The result in Table4 shows that male students taught physics using self-regulated learninghad a mean delayed posttest score (retention) of 32.88 (SD=5.95), while their female counterparts had a mean delayed posttest score of 31.40 (SD=5.80).The average score gap is 1.48. This indicates that a variation exists in the delayed posttest scores of the groups.

H_{02}: No significant variation exists in the delayed posttest mean achievement scores of male and female students taught physics with self-regulated learning

Table 5:

Independent Sample t-test comparison of the variation exists in the delayed posttest mean achievement scores of male and female students taught physics with self-regulated learning

Gender	N	$\bar{X}$D-Posttest	$\bar{X}$Diff	SD	Df	t-cal	Sig. (2-tailed)	Decision
Male	52	32.88	1.48	5.95	100	1.28	0.205	**H_{02} is not rejected**
Female	50	31.40		5.80				

Table 5indicates that the t-value of 1.28 with a p-value of 0.205 is obtained at 0.05 level of significance when the delayed posttest mean achievement (retention) scores of male and female students instructed physics with self-regulated learning were compared. Since the p-value of 0.205 is greater than the significance value of 0.05 ($p > 0.05$), the null hypothesis, $H_{02,}$ is not rejected**.** Therefore, there is no statistically significant difference in the delayed posttest mean achievement scores of male andfemale students who were taught physics using the mind mapping instructional strategy.

Research Question 3: How do male and female students who were taught physics with mind maps differ in their delayed posttest mean achievement scores?

Table 6:

Descriptive statistics of mean and standard deviation comparison of how male and female students who were taught physics with mind maps differ in their delayed posttest mean achievement scores

Gender	N	$\bar{X}$D-Posttest	$\bar{X}$Diff	SD
Male	56	37.93	0.74	5.23
Female	63	38.67		5.14

The result in Table6 shows that male students instructed physics with mind maps had an average delayed posttest score (retention) of 37.93 (SD=5.23), while their female counterparts had an averagedelayed posttest score of 38.67(SD=5.14).The average score gap is 0.74. This indicates that there is a variation between the delayed posttest scores of the groups.

H_{03}: No significant variation exists in the delayed posttest mean achievement scores of male and female students taught physics with mind maps.

Table 7:

Independent Sample t-test comparison of the variation exists in the delayed posttest mean achievement scores of male and female students taught physics withmind maps

Gender	N	$\bar{X}$D-Posttest	$\bar{X}$Diff	SD	Df	t-cal	Sig. (2-tailed)	Decision
Male	56	37.93	0.74	5.23	117	0.889	0.376	**H_{02} is not rejected**
Female	63	38.67		5.14				

Table 7indicates that the t-value of 0.889 with a p-value of 0.376 is obtained at 0.05 level of significance when the delayed posttest average achievement scores of male and female students instructed physics with mind map were compared. Since the p-value of 0.376 is greater than the significance value of 0.05 ($p > 0.05$), the null hypothesis, $H_{02,}$ is not rejected**.** Therefore,no significant variation exists in the delayed posttest mean achievement scores of male and female students taught physics with mind maps.

Research Question 4: How do the methods and gender interact to affect students' delayed posttest mean achievement scores?

Table 8:

Descriptive statistics of mean and standard deviation showinghow the methods and gender interact to affect students' delayed posttest mean achievement scores?

Groups	N	Sex	$\bar{X}$	**SD**
SRLIS	52	Male	32.88	5.95
	50	Female	31.40	5.80
	102	Total	32.16	5.89
MMIS	56	Male	37.93	5.23
	63	Female	38.67	5.14
	119	Total	38.32	5.17
LM	61	Male	28.36	4.15
	40	Female	28.60	3.48
	101	Total	28.46	3.89

Table 8 shows the nature of the interaction between instructional methods and gender on physics students' delayed posttest average achievement scores. The table shows that the malestudents instructedwith self-regulated learning had a delayed posttest average achievement score of 32.88 (SD=5.95), while the female students had 31.40 (SD=5.80).For the MMIS group, the male students had a delayed posttest average achievement score of 37.93 (SD = 5.23), while their female counterparts had 38.67 (SD = 5.14).For the LM group, the male students had a delayed posttest average achievement score of 28.36 (SD=4.15), while the female students had28.60 (SD=3.48).

H_{04}: No significant interaction exists between methods and gender in influencing students' delayed posttest mean achievement scores.

Table 9:

Results of the ANCOVA examining the interaction effect of methods and gender on students' delayed posttest mean achievement scores

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	7880.569[a]	6	1313.428	71.316	.000
Intercept	2657.864	1	2657.864	144.315	.000
Pretest	2305.306	1	2305.306	125.172	.000
Groups	6671.924	2	3335.962	181.134	.000
Sex	15.691	1	15.691	.852	.357
Groups * Sex	91.399	2	45.699	2.481	.085
Error	5801.381	315	18.417		

Total	370172.000	322
Corrected Total	13681.950	321

a. R-squared = .576 (Adjusted R-squared = .568)

The results from Table 9 show that no significant interaction exists between methods and gender in influencing students' delayed posttest mean achievement scores, $F(2, 315) = 2.481$, $p = .085$. This indicates that the efficacy of the instructional methods on students' delayed posttest mean achievement scores did not depend on gender. In other words, male and female students benefited similarly from the different teaching strategies. Therefore, $H_{04,}$which states that no significant interaction exists between methods and gender in influencing students' delayed posttest mean achievement scores, is not rejected.

Discussion

The study's first finding demonstrated that studentsinstructed physics with self-regulated learning, mind maps, and lecture methods differedsignificantly in their delayed posttest mean achievement scores. The Scheffe post-hoc analysis showed the mind map was the most effective method, followed by self-regulated learning,in contrast to the lecture method,which was the least effective.This suggested that student-centered and cognitively engaging instructional strategies, particularly mind maps, are more effective than the traditional lecture method in promoting students' long-term retention of physics concepts. The superiority of mind maps over others may be becausemind maps arousedstudents' curiosity to learn and increased their critical thinking, and they were able to express themselveseffectively with mind maps. This finding aligns with those of Akanbi, Olayinka, Omosewo, and Mohammed(2021);Akinwumi and Bello (2015); andBalm (2013), who, in their respective studies, asserted that a statistically significant difference existed in favour of the mind map method over the lecture method regarding students' retention.

The study's second finding indicated that male and female students instructed in physics through self-regulated learning strategy did not differ significantlyin their delayed post-test mean achievement (retention) scores. Although male students recorded a slightly higher mean score in comparison to their female counterparts, the observed difference was not significant at the 0.05 level. This indicates that the strategy was equally effective in strengthening long-term retention of physics concepts among both genders.The finding indicates that gender did not significantly influence students' retention of physics concepts when taught using the self-regulated learning strategy. This suggests that self-regulated learning provides an equitable learning environment that supports both genders equally in retaining learned physics content over time. By encouraging goal setting, self-monitoring, self-evaluation, and independent learning, the strategy appears to minimize gender-related disparities often observed in science achievement. This finding is consistent with those of Zimmerman (2013), Schraw, Crippen, and Hartley (2006), and Jirgba and Bur (2019), who found no significant gender differences in achievement when students were exposed to self-regulated or metacognitive-based learning strategies.

The study's third finding indicated that male and female students instructed in physics through mind map strategy did not differ significantlyin their delayed post-test mean achievement (retention) scores.This also suggests that the mind map strategy is not genderbiased, as both genders actively interacted with one another in the course of the instructional process, and they benefited equally.This outcome may be ascribed to the visual, integrative, and learner-centered nature of the strategy, which supports meaningful learning by organizing information spatially and linking new concepts with prior knowledge, irrespective of gender differences.The finding aligns with those of Akanbi, Olayinka, Omosewo, and Mohammed (2021);Akinwumi and Bello (2015);Balm(2013);Obunwo (2014); and Okeke (2011), who found no statistically considerable variation between the delayed post-test mean achievement (retention) scores of male and female students instructed inphysicswith mind mapstrategy in their respective studies.

The study's fourth and final finding demonstrated that there was no statistically substantial interaction effect between instructional methods and gender. This result indicates that the efficacy of the methods on students' retention did not depend on gender. In other words, both male and female students benefited similarly from the instructional strategies employed, regardless of the method used. The failure to observe a significant interaction effect suggests that the instructional methods were gender-friendly and equally effective for both sexes. With this, it can be inferred that both male andfemale students exposed to the same treatment did not differ significantly in their retention scoresin physics. The finding also agrees with that ofAkanbi,Olayinka,Omosewo, and Mohammed(2021); Adeyemi (2012); Ezedinma and Nwosu (2018); and Okotcha (2018), who in various investigations found no evidence of a notable interplay between methods and gender on students' achievement and retention.

Conclusion

From the results of the study, it was concluded that mind map instructional strategy is more effective in facilitating physics students' retention than the self-regulated learning instructional strategy and the lecture method. Furthermore, self-regulated learning and mind map instructional strategies are not gender-biased regarding enhancing physics students' retention, and self-regulated learning, mind maps,and lecture methods do not interact with gender to influence physics students' retention.

Recommendations

The following are therefore recommendedas a result of the study's findings:

1. mind map instructional strategy should be integrated into the teaching and learning of the physics curriculum concepts at the senior secondary school level of education towards promoting achievement and retention of students in physics.
2. mind mapping strategy should be integrated into physics instruction for male and female students at the senior secondary level because it facilitates better retention

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