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MANIPULATING SECONDARY SCHOOL STUDENTS' ACADEMIC PERFORMANCE IN PHYSICS THROUGH THE USE OF METACOGNITIVE INSTRUCTIONAL STRATEGY

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Abstract
This study evaluated how integrating metacognitive instructional approaches affects the academic performance of Senior Secondary II physics students in Taraba State, Nigeria. Using a quasi-experimental, pretest-posttest control group design, researchers selected 200 students (117 male, 83 female) from a target population of 5,361 learners. Primary data were gathered using a 50-item Physics Performance Test with a reliability coefficient of 0.87. Analysis of Covariance (ANCOVA) revealed that learners instructed using metacognitive techniques achieved significantly higher scores than those taught with conventional methods (ANCOVA showed a significant treatment effect, (1,197) =370.293, $p<.001$, Partial $\eta^2=.653$). The experimental group recorded a mean score improvement of 13.83, demonstrating a substantial enhancement in their grasp of physics concepts. Additionally, the research found the metacognitive strategy to be highly gender-friendly, yielding no significant performance variations between male and female participants ($F(1, 112) = 1.004$, $p =.32 > 0.05$, Partial $\eta^2=.009$). Given these inclusive and highly positive outcomes, the researchers strongly recommend that the Ministry of Education organize workshops to equip physics educators with the necessary skills to effectively implement these teaching methods in their classrooms.

Keywords: Metacognitive instructional strategy, academic performance, physics, secondary school, conventional strategy, quasi experimental design

Introduction

Science is a great enterprise that nations depend on to advance scientifically and technologically. Science can be thought of as a body of knowledge (the things we have already discovered), and the process of acquiring new knowledge (through observation and experimentation testing and hypothesizing). Hassaskhah and Zamir (2018) stated that science is both a process (scientific method) and a product (knowledge, facts and principles). Knowledge and process are interdependent since the knowledge acquired depends on the questions and methods used to find the answers. Both the process and product of science are acquired through education and this is a specialized type of education such as science education. The field of 'science' is often grouped into: natural science—life or biological science (the study of living organisms) and physical science (the study of the material universe including physics, chemistry and space science among others) and social science—the study of society and people (such as anthropology, psychology); formal science and the study of logic and mathematics, applied science disciplines that rely on science and use existing scientific knowledge to develop new applications, such as in engineering, robotics, agriculture and medicine (Nsude, 2020). Both natural science and social science are known as empirical sciences. This means that any theory must be based on observable phenomena, reproducibility of results and peer review. Science plays important roles in the society because it relates to our daily life and career. The importance of science in our society made the Federal Government of Nigeria, through the Federal Ministry of Education to introduce science subjects in the nations' secondary school curriculum. Physics is one of such subjects introduced.

Physics is the foundational physical science linking matter, energy, and their interactions through mathematics. Traditionally, it covers mechanics, heat, and electromagnetism, modern physics—rooted in quantum theory and has expanded to include atomic, nuclear, and solid-state studies (Ayatse, et al. 2021), alongside applied areas like meteorology. Investing in physics is crucial because it drives technological innovation, creates essential medical tools (like X-rays and MRI), and shapes our fundamental understanding of fields from biology to cosmology.

Educational experts recognize that all students can succeed academically when provided with the right learning conditions (Filgona, et al. 2017). This pedagogical shift has transformed classroom dynamics. By fostering inclusive, hands-on learning, it moves students beyond traditional, abstract lectures. Specifically, metacognitive instructional strategies could serve as an effective remedy to help students overcome learning difficulties in physics.

The most effective way to learn is when teachers and students actively work together, rather than students just listening passively. In a learner-centered strategy, the learners play an active part in their own learning, while the teacher plays the role of a facilitator. (Yemi et al., 2018) pointed out that there are various learner-centered instructional strategies, such as field trips, modular instructions, cooperative learning, peer tutoring, active learning methods, inductive methods and project techniques among others. Despite the fact that these strategies could be used to improve learners' achievements, most teachers are still inclined to the use of chalk and talk method with its antecedent inadequacies (Okenyi, 2022). On this note, therefore, the study considered the use of a metacognitive learning strategy in improving student performance and retention physics.

Nzeadibe, et al. (2019) define meta-cognition as a level of thinking that involves active control over the process of thinking that is used in learning situations. Meta-cognitive strategy refers to one's knowledge concerning one's cognitive processes. Cognitive processes or activities mean elaboration of the methods used in teaching. The function of cognition is to solve problems, to bring cognitive enterprises to a good end (Okoza & Aluede, 2014). Onovughe et al (2011) further stated that planning the way of strategizing a learning task, monitoring comprehension, and evaluating the progress towards the completion of a task are skills that are meta-cognition in nature. Meta-cognitive activities involve necessary components for successful problem solving. Such components include mathematical knowledge and experience, separating relevant from irrelevant information, and the ability to use a variety of strategies (Schneider &Artelt, 2010). According to Martinez (2016), meta-cognition is the monitoring and control of thought. Thus, Kuhn and Dean (2004) regard meta-cognition as awareness and management of one's own thought. Based on Kuhn and Dean's work, meta-cognition is what enables a learner who has been taught a particular strategy in a particular problem context to retrieve and use that same strategy in a similar context. Hence, learning strategy is what a teacher or learner arranged to establish interaction between the teacher, the students, and the subject matter, of any combination of these three dimensions (Vijaya &Jinto, 2014). Cognitive strategies are used to help an individual achieve a particular goal (e.g, understanding a text) while meta-cognitive strategies are used to ensure that the goal has been reached (e. g quizzing oneself to evaluate one's understanding of that test). Therefore, meta-cognitive strategies are actions which go beyond purely cognitive devices and which provide learners to coordinate their own learning process (Begam, 2017). The author further stated that, meta-cognitive strategies are sequential processes that one uses to control cognitive activities, and to ensure that a cognitive goal is achieved. These processes help to regulate and oversee learning, and consist of planning and monitoring cognitive activities, as well as checking the outcomes of those activities.

Academic performance represents a student's standing at any given time, measured by educational performance test scores and cumulative milestones, such as degrees and certificates (Daniels & Schouten, as cited in Mekonnen, 2014). It also measures how successfully individuals achieve specific learning goals within instructional environments like schools and universities (Steinmayr, et al.2015). The core outcomes of this educational process include positive shifts in knowledge, skills, and attitudes (Chinyere, et al. 2019). This research focuses specifically on Nigerian secondary school students, evaluating academic success based on overall scores in external WASSCE and/or NECO examinations. Poor performance is defined as falling below the expected baseline required for admission into higher education institutions. The concepts of "projectiles," "vectors and scalars," and "equilibrium of forces" were selected from the Senior Secondary School year two (SS 2) physics curriculum due to their critical relevance to modern science and technology. Using an interactive and learner-friendly meta-conceptual teaching method for these topics is hypothesized to benefit both male and female physics students.

Previous studies tend to show that students' achievement in physics is very poor due to the insufficient manpower, lack of teaching equipment, poor attitude of students and poor understanding of the concepts involved in Physics (Abonyi & Ike, 2014). Others are poor method of teaching and nature of curriculum (Achor et al., 2022b). It is widely argued that Physics education in Nigeria tends to be rigid and disconnected from the student. A learner-centered alternative suggests that children form cognitive representations of nature based on their cultural and environmental interactions. By incorporating these concept maps into the instructional design, teachers can effectively bridge this gap and optimize student achievement. One of the most important targets of modern education is to instil in learners the ability to solve problems. A physics teacher takes no exception to this considering the fact that physics is regarded as the bedrock of technological development worldwide in both developed and developing countries (Nwuese &Wanjal, 2014).

Gender has been noted by researchers over the years as having impact on performance in Physics and its related disciplines (Ezirim, 2016). Longe and Adedeji (2013) even stressed that science, technology and their related disciplines are male-reserved while Art and Humanities are female reserved. This belief makes boys appear to have a natural positive attitude towards science and technical subjects while girls show more inclination to Arts and Humanities. The problem is even compounded by the fact that most science educators give masculine outlook to science subjects such as chemistry and physics (Adeyemo et al., 2015); encouraging females to go rather for biology, agricultural science and home economics which they consider to be more female-friendly science subjects. Some other researchers (Nwankwo & Okoye, 2015; Orefor, 2016) opined that gender has no influence on students' achievement in the sciences. All these and related treatments make girls have phobia for science and science-related subjects which definitely affect their future career-choice and eventual achievement. Due to lack of consensus regarding the issue of gender and science and more importantly to capture the interest of girls, and consequently improve their performance in physics and other science related carriers, there is a need therefore to try such innovative strategy as metacognitive teaching approach to see what effect it will have on performance of male and female students in the sciences especially Physics.

Theoretical Foundation for this Study

The theoretical backing to this study lies in Lev Vygotsky's 1978 theory which posits that higher mental functions, like metacognition, begin as social interactions before being internalized by the individual. In secondary physics, teachers use this by scaffolding student thinking within their Zone of Proximal Development (ZPD)—the space where they can solve problems with guidance but not alone. Vygotsky's framework directly connects to metacognitive strategies (planning, monitoring, evaluating) in three practical ways for the physics classroom. That by hearing how a more knowledgeable peer plans or checks their work (monitoring), the student absorbs the methodology and incorporates it into their own mental toolkit. Therefore, the teacher acts as the More Knowledgeable Other (MKO), assessing the gap between what a student can do alone and what they can do with help. Lev Vygotsky's 1978 sociocultural framework connects to metacognitive strategies by showing how higher mental functions develop through social interaction and cultural tools, moving from external guidance to internal self-regulation. During planning in Vygotsky's theory, we have:

a. Adult mediation: Adults and teachers help set goals and plan steps during joint activities.

b. Scaffolding: Helpers structure the task so the learner can see how to organize future actions.

c. Internalizing plans: Children adopt the organized dialogue of adults to plan their own independent work later.

At monitoring stage in Vygotsky's theory we have:

a. Co-regulation: Peers or teachers monitor performance and provide feedback in real time.

b. Private speech: Children talk out loud to track their own progress and fix errors while working.

c. Self-guidance: Out loud speech becomes silent inner speech used to check focus and understanding during a task.

While Evaluating in Vygotsky's theory, there shall be:

a. Shared reflection: Joint evaluation with a more knowledgeable other helps assess what went right or wrong.

b. Zone of Proximal Development: Evaluation shows where the learner needs more help and where independent mastery begins.

c. Autonomous mastery: The learner applies the shared standard of success to judge their final output alone.

Statement of the Problem

Student performance in senior secondary school physics has historically been poor, largely due to a continued reliance on traditional "chalk and talk" instruction. To effectively teach this highly practical subject, educators must transition to active, learner-centered methods. By adopting collaborative and problem-solving strategies, teachers can promote active participation and deeper cognitive engagement. According to the 2022 WAEC Chief Examiners' reports, candidates' subpar performance in the SSCE physics examination is directly linked to a poor comprehension of core theories and foundational principles. Most students who study physics are unable to have appropriate understanding of physics concept (Achor et al., 2022a). Research reports indicate that students' achievement in secondary school physics is very poor (Otor et al. 2017). Available statistics from West-African Examination Council Chief Examiners Report (WAEC, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020) on senior secondary schools achievement in physics specifically in Jalingo Metropolis reveals a poor trend at the senior secondary school certificate examination (SSCE) in physics, 2011 (15.71%), 2012 (16.25%), 2013 (9.25%), 2014 (11.68%), 2015 (32.60%), 2016 (10.50%), 2017 (32.10%), 2018 (43.65%), and 2019 (7.85%), and 2020 (19.67%) respectively.

While previous research indicates that problem-solving and collaborative metacognitive strategies improve academic performance across various disciplines, the specific impact of these methods on physics performance remains unclear. Consequently, this study investigates whether implementing these two metacognitive strategies effectively enhances physics learning among senior secondary school students.

Purpose of the Study

The primary purpose of this study is to explore the application of metacognitive instructional strategies to improve Physics performance among secondary school students in Taraba State. Specifically, it sought to:

I. determine the performance of students taught using Metacognitive Instructional Strategy and conventional teaching method

II. compare the performance of male and female students taught with Metacognitive Instructional Strategy

III. determine the interaction effect of teaching strategies (metacognitive and conventional) and gender on students' performance

Method

This study utilizes a quasi-experimental research methodology, specifically a non-equivalent control group design. It incorporates a pre-test and post-test. This is a 2x2 factorial design. While true experimental designs are recognized as the most powerful and valid frameworks for confidently identifying cause-and-effect relationships (Emaikwu, 2010), this particular research design is selected to demonstrate the causal impacts between variables (Achor & Agogo, 2019). This approach is highly suitable for evaluating how specific learning strategies affect students' physics performance. Furthermore, it allows the research to proceed without disrupting regular school activities, as intact classes are used rather than randomized groups. The researchers assigned the intact classes to either an experimental group (E) or a control group (C). The teaching made to the two groups or simply treatment is the source of manipulation while the outcome or performance is the effect of the manipulation.

The study population comprised 5,361 students that offer physics—4,035 males and 1,326 females enrolled in 44 public secondary schools across three local government areas in the Jalingo Education Zone during the 2024/2025 academic session (Taraba State Post Primary Schools Management Board Zonal Monitoring Office Jalingo, 2024). From this group, a purposive, multi-stage sampling technique was used to select a representative sample of 200 students (117 males and 83 females) from two co-educational schools, as attending a co-educational school was a strict criterion for participation.

The sampling procedure first involved selecting specific local government areas randomly and then choosing two co-educational schools out of the zone purposely. Within these schools, intact classes were used rather than randomized individual subjects. To assign treatment conditions, a class was randomly assigned to the experimental group and the remaining intact class that was not selected for the metacognitive instructional strategy was designated as the control group.

Instruments, Validation band Reliability

To collect data for the study, the researcher developed a single instrument called the Physics Performance Test (PPT). Divided into two parts, Section A collected demographic details like student gender and school name. Section B assessed academic performance, consisting of 50 multiple-choice questions on waves, adapted from standardized WAEC tests. Students were instructed to select the single correct answer from four options (A-D).

To establish the face and content validity of the 50-item Physics Performance Test (PPT), three experts—two specializing in science education and one in measurement and evaluation reviewed the instrument. They evaluated the draft questions for clarity, reading level appropriateness, and the plausibility of the distracters, cross-referencing their assessments with the study's title, objectives, research questions, and table of specifications.

The methodology of the study involved administering a thirty-item Physics Performance Test (PPT) to a sample of thirty Senior Secondary 1 (SS11) students at Government Secondary School, Zing. To ensure the instrument's consistency, the resulting test scores were subjected to the Kuder-Richardson Formula 20 (K-R20). This statistical analysis yielded a strong reliability coefficient of 0.87, demonstrating that the assessment tool was highly dependable and suitable for measuring the students' academic abilities in the subject.

Method of Data Collection
Treatment Procedure

Phase I: Training

Before the study began, the researcher conducted four-hour training sessions over the course of one week for two research assistants across two schools. The training covered the Metacognitive instructional strategy and the Conventional method. It included practical teaching demonstrations to familiarize the assistants with the materials and prepare them to help administer pre-tests.

Phase II: Student Treatment

Week 1: Pre-tests were administered to both the experimental and control groups.

Week 2: The experimental group learned the concepts of waves using the metacognitive instructional strategy. They engaged in the four phases of the learning cycle and recorded their reflections in provided exercise books. Meanwhile, the control group discussed the same wave concepts conventionally with the research assistants.

Week 3: Experimental students compared data with the help of the research assistants, classified waves according to operation, verbalized their ideas, and wrote reflections in their journals. The control group continued with normal lesson activities.

Week 4: The experimental group covered additional wave concepts under the researcher's supervision, strictly following the metacognitive plan. Afterward, an assessment on machines and waves was conducted, requiring students to classify waves and answer questions while assistants recorded observations. The control group followed standard lessons. At the end of the week, all students in both experimental and control groups completed a post-test.

Ethical Considerations
Ethical issues addressed in this study includes:

Ministry/District Clearance: School board approval was sought to access the schools.

Principal Permission: Official clearance was obtained from school principals to interact with students and teachers.

Parental Consent: Signed permissions from parents or guardians were obtained as the students were legal minors.

Student Assent: Voluntary, written agreement was obtained from the secondary students after explaining the study in simple terms.

Right to Withdraw: Explicit assurance was given to the students that they could opt out at any time without academic penalties.

No Disruptions: It was ensured that the research integrated smoothly into the regular school timetable without causing stress.

Anonymization: Using codes or pseudonyms instead of student names, school names, or admission numbers during the study.

Results

To address the research questions, we used means, standard deviations, and line and bar graphs to evaluate the students' pre-test and post-test physics performance. To test our hypotheses at a 0.05 significance level, we applied pairwise comparisons and a three-way ANCOVA to account for any baseline differences between the groups. The research questions and corresponding hypotheses were addressed in this section

Performance of Students taught using Metacognitive Instructional Strategy and Conventional Teaching Method

Table 1: Mean Performance Scores of Students taught using Metacognitive Instructional Strategy and Conventional Teaching Method

Strategies		Pre-Performance	Post Performance	Mean gain
Metacognitive Instructional Strategy	Mean	14.11	35.27	21.16
	N	115	115	
	Std. Deviation	2.72	5.51	
Conventional Teaching Method	Mean	13.60	20.93	7.33
	N	85	85	
	Std. Deviation	2.44	4.83	
Mean difference				13.83

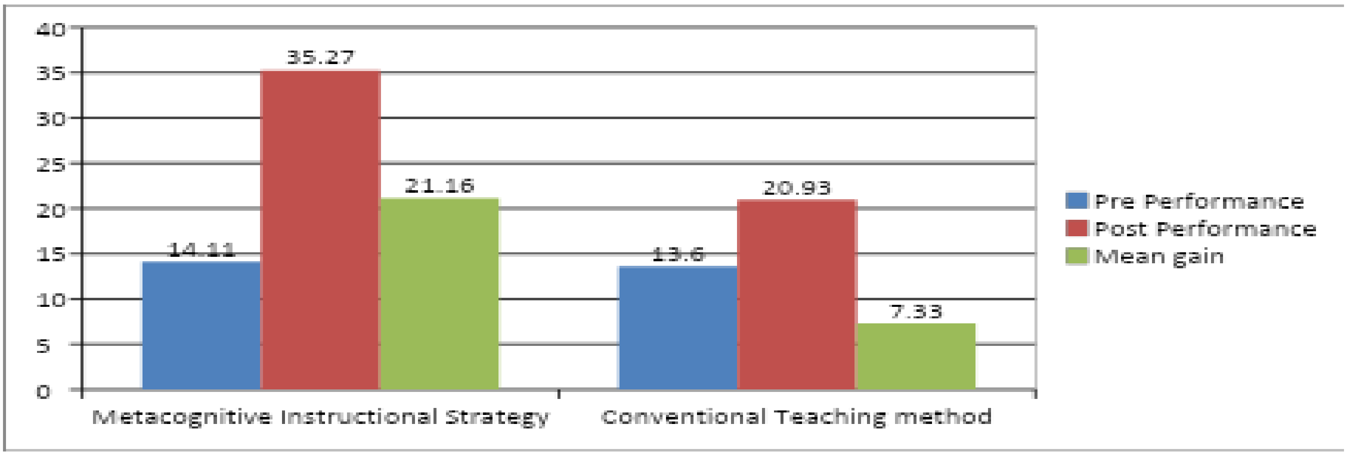

Figure 1: Pretest, Posttest and Mean Gain in Performance Scores of Students taught using Metacognitive Instructional Strategy and Conventional Teaching Method

A total of 200 students participated in the study, comprising 115 in the experimental group taught via the Metacognitive Instructional Strategy and 85 in the control group taught using traditional methods. Both groups demonstrated comparable foundational knowledge initially, with no significant differences in their pre-test scores (experimental mean = 14.11, SD = 2.72; control mean = 13.60, SD = 2.44). Following the instruction, the experimental group significantly outperformed the control group, achieving a final mean score of 35.27 (SD = 5.51) compared to the control group's 20.93 (SD = 4.83). Consequently, the experimental group achieved a substantial mean gain of 21.16, greatly exceeding the 7.33 mean gain of the control group. Overall, the final results highlight a significant 13.38-point difference in mean performance scores, heavily favouring students instructed with the Metacognitive Instructional Strategy. A visual representation of these performance metrics is detailed in Figure 1.

Table 2: ANCOVA of Performance Scores between Students taught using Metacognitive Instructional Strategy and Conventional Teaching Method

Dependent Variable: Post performance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10421.033[a]	2	5210.516	191.959	.000	.661
Intercept	4047.130	1	4047.130	149.099	.000	.431
Pre-performance	88.073	1	88.073	3.245	.073	.016
Strategies	10051.201	1	10051.201	370.293	.000	.653
Error	5347.347	197	27.144			
Total	185014.000	200				
Corrected Total	15768.380	199				

a. R Squared = .661 (Adjusted R Squared = .657)

The results presented in Table 2 indicate a statistically significant difference in the average performance of students who were taught using the Metacognitive Instructional Strategy compared to those who learned through conventional teaching methods. This is based on the statistical findings, ($F(1, 197) = 370.293$, $p < .05$). Consequently, the initial null hypothesis must be rejected. Furthermore, the calculated partial eta square value of 0.653

reveals a large effect size, demonstrating that an impressive 65.3% of the overall variance in student academic performance can be directly attributed to the specific instructional strategies used in the classroom.

Performance of Male and Female Students taught with Metacognitive Instructional Strategy

Table 3: Mean Performance Scores of Male and Female Students taught with Metacognitive Instructional Strategy

Gender		Pre performance	Post performance	Mean gain
Male	Mean	14.15	35.65	21.50
	N	75	75	
	Std. Deviation	2.65	5.84	
Female	Mean	14.05	34.55	20.50
	N	40	40	
	Std. Deviation	2.87	4.82	
Mean difference				1.00

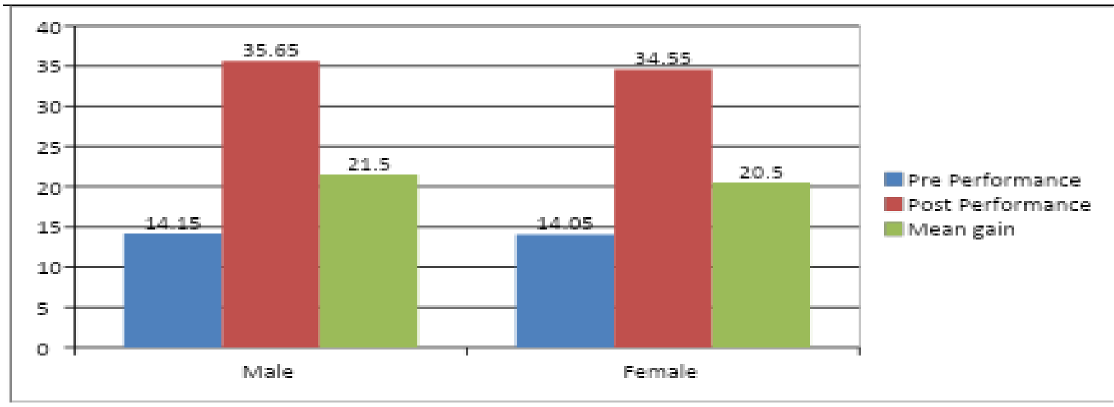

Figure 2: Gender-Based Pretest, Post-test, and Mean Performance Gains of Students Instructed via Metacognitive Strategies

As shown in Table 3, the sample taught using the Metacognitive Instructional Strategy comprised 75 male and 40 female students. Prior to the intervention, both groups exhibited similar baseline performance; male students obtained a pre-test mean score of 14.15 (SD = 2.65), while female students scored a mean of 14.05 (SD = 2.87). following the treatment, post-test scores increased noticeably for both genders. Males achieved a post-test mean score of 35.65 (SD = 5.84), and females achieved a mean of 34.55 (SD = 4.82).

A comprehensive analysis of the empirical data indicates that male students experienced slightly better overall academic growth compared to their female counterparts. Specifically, the male cohort registered a mean performance gain of 21.50, outpacing the 20.50, improvement achieved by the female cohort. Consequently, this translates into a narrow, yet observable, mean score difference of 1.00, favoring the male students. To further illustrate these educational outcomes, the variations in pre-test, post-test, and average score distributions across both demographics are fully detailed and visually mapped out in Figure 2.

Table 4: ANCOVA of Performance Scores of Male and Female Students taught with Metacognitive Instructional Strategy

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	196.981[a]	2	98.490	3.372	.038	.057
Intercept	3405.422	1	3405.422	116.579	.000	.510
Pre-performance	165.224	1	165.224	5.656	.019	.048
Gender	29.336	1	29.336	1.004	.318	.009
Error	3271.663	112	29.211			
Total	146522.000	115				
Corrected Total	3468.643	114				

a. R Squared = .057 (Adjusted R Squared = .040)

An analysis of the data (Table 4) reveals no statistically significant gender-based differences in student outcomes. Specifically, male and female learners demonstrated comparable mean performance scores when utilizing the Metacognitive Instructional Strategy. Since the probability value of 0.318 exceeds the standard benchmark of 0.05, the null hypothesis was maintained. Furthermore, the partial eta-squared value of 0.009 demonstrates that gender accounts for merely 0.9% of the variance in overall performance.

Interaction Effect of Teaching Strategies and Gender on Students' Performance

As shown in the profile plot (Figure 3) and Table 5, there is no significant interaction effect between teaching strategies and gender on academic performance. The intersection of the male and female performance lines at the conventional teaching method demonstrates that gender and instructional method are interdependent in their impact.

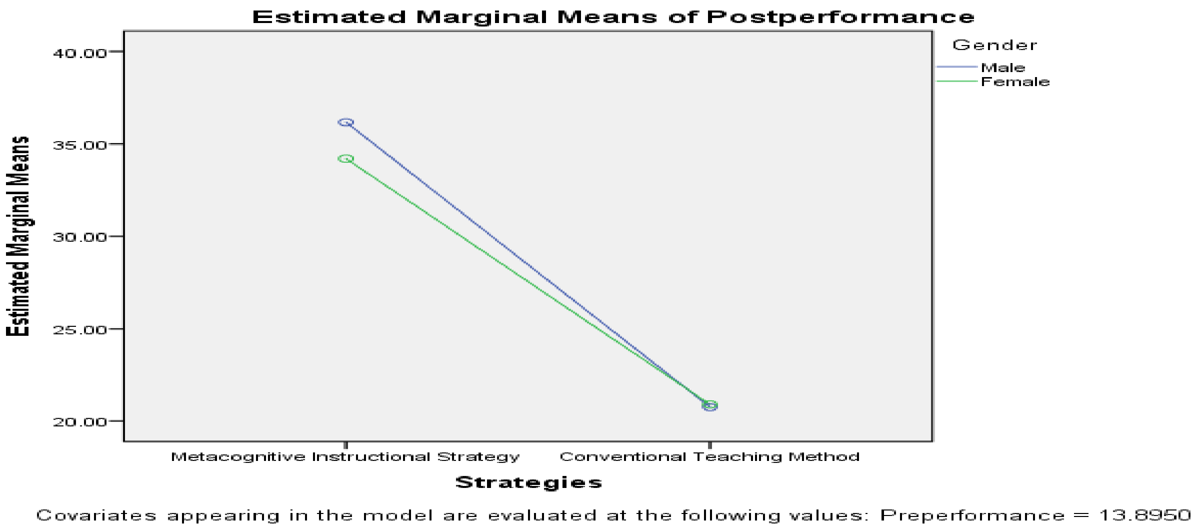

Figure 3: Interaction Effect of Teaching Strategies and Gender on Students' Performance

Table 5: ANCOVA of Interaction Effect of Teaching Strategies and Gender on Students' Performance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10532.774[a]	4	2633.193	98.073	.000	.668
Intercept	3985.389	1	3985.389	148.436	.000	.432
Pre-performance	93.565	1	93.565	3.485	.063	.018
Strategies	9177.947	1	9177.947	341.832	.000	.637
Gender	37.570	1	37.570	1.399	.238	.007
Strategies * Gender	49.932	1	49.932	1.860	.174	.009
Error	5235.606	195	26.849			
Total	185014.000	200				
Corrected Total	15768.380	199				

a. R Squared = .668 (Adjusted R Squared = .661)

Based on the statistical analysis presented in Table 5, the combined influence of different teaching strategies and student gender yielded no statistically significant impact on overall academic outcomes. Because of this lack of a meaningful difference, the original null hypothesis was maintained. Furthermore, the effect size demonstrated that this combined interaction accounted for a negligible amount of the total variance (0.9%) in the test scores.

Discussion of Findings

Discussion in this section is made under three sub-headings:

Performance of Students taught using Metacognitive Instructional Strategy and Conventional Teaching Method

The study indicates a statistically significant difference in the average performance of students who were taught using the Metacognitive Instructional Strategy compared to those who learned through conventional teaching methods. The experimental group achieved a substantial mean gain of 21.16, greatly exceeding the 7.33 mean gain of the control group. The empirical findings are corroborated by a substantial body of recent pedagogical research. For instance, Agu and Ebele's study (2024) established that regulatory self-questioning strategies markedly elevate the geometric comprehension of senior secondary students compared to traditional instruction. Similarly, Okafor et al. (2023) demonstrated that metacognitive approaches surpass standard lecture formats in fostering deep learning. Furthermore, Koroko et al.'s work (2023) confirms that these techniques are highly effective in boosting both the interest and achievement of junior secondary learners in Basic Science and Technology. Finally, the outcomes mirror the conclusions drawn by Achor et al. (2022b), who validated that cultivating metacognitive awareness directly impacts the academic performance scores of Basic Eight students in Social Studies. Ultimately, integrating metacognition into the curriculum proves to be a vastly superior method for augmenting student success.

Several studies highlight the effectiveness of metacognitive and collaborative approaches in improving student outcomes. The use of metacognitive learning cycles significantly enhances students' interest and academic performance in physics Elom and Aja (2024), Uzobuike and Okoli, (2020). Similarly, metacognitive scaffolding yields superior academic results compared to traditional lectures (Agu & Iyamu, 2020). On a broader scale, students who frequently apply these techniques achieve higher average scores (Neşe, 2021), and metacognition noticeably boosts overall achievement in the sciences (Oyovwi, et al. 2021). Furthermore, collaborative learning strategies have been shown to outperform problem-solving methods in specific subjects like geometry (Nzeadibe et al. 2019).

The present findings align with the conclusions drawn by Achufusi et al. (2019), which demonstrated a statistically significant improvement in the academic performance of physics students. Specifically, their study established that learners taught utilizing a metacognitive learning model achieved considerably higher mean scores compared to their peers who were instructed through traditional lecture methods. The finding agrees with Udofia and Uduak (2019) that there was significant difference in achievement scores of chemistry students taught alkanols using KWL and those taught with expository strategy. The finding agrees with Dike et al (2017) that students taught with thinking-aloud metacognitive strategies performed better in chemistry achievement test followed by self-assessment metacognitive strategy than the conventional strategy. The finding agrees with Jayapraba (2013) that the metacognitive instructions were most effective in enhancing academic performance. The finding agrees with Venus (2013) that there is a statistically significant difference in the post-test scores of the experimental groups and control groups.

In this study, using metacognitive instructional strategies empowered students to become self-regulated learners. By treating learning as a flexible, growing skill rather than a fixed trait, this approach encouraged students to evaluate their own thinking and draw on prior knowledge. Developing this cognitive and task awareness boosted student motivation and improved academic grades, ultimately accounting for the significant performance difference between students taught via metacognitive methods and those taught using conventional approaches.

Curricular implications demand a shift from passive, teacher-led instruction to active, student-centered learning. Because the metacognitive strategy yielded a substantial ($\Delta\bar{x}$ = 21.16) mean gain compared to the control group's ($\Delta\bar{x}$ = 7.33), curricula must explicitly mandate the teaching of learning processes alongside core subjects like physics.

Performance of Male and Female Students taught with Metacognitive Instructional Strategy

When applying the Metacognitive Instructional Strategy, female and male students show comparable results in physics. Findings indicate a minor, non-significant difference of 1.00 in mean performance scores favoring males, demonstrating that this teaching method is highly gender-friendly. This outcome aligns with research by Okafor et al. (2023) and Agu and Iyamu (2020), who similarly found no significant gender disparities in student performance when utilizing metacognitive teaching techniques. Furthermore, it supports Nzeadibe et al. (2019) regarding geometry, where gender did not significantly influence achievement. However, these results differ from the findings of Achor et al. (2022b), who observed a significant impact of metacognitive awareness on the performance scores of both male and female students in Social Studies.

This gender neutrality occurs because the strategy focuses on teaching students how to set their own learning goals and plan effectively. Before beginning a lesson, teachers provide students with clear objectives regarding what they are expected to learn. Students then consider these goals, plan accordingly, and execute their plans irrespective of their gender. The finding indicates that both innovative, student-centered interventions (like metacognitive strategies) and traditional conventional methods operate independently of a student's biological sex. Educators can implement metacognitive tools—such as thinking-aloud protocols, self-assessment, or planning matrices—with confidence that they will equitably benefit or influence both male and female learners.

Interaction Effect of Teaching Strategies and Gender on Students' Performance

Overall, the research revealed that there was no significant interaction effect of teaching strategies and gender on students' academic performance. The instructional strategies, that is, metacognitive strategy and the conventional methods as well as the presence of male and female students in both strategy class made some influence though not statistically significant. This is a factorial design of 2x2. The primary outcome of this analysis is the lack of a statistically significant interaction effect between instructional strategies (metacognitive strategy versus conventional methods) and gender on students' academic performance. In statistical terms, this indicates that the effectiveness of the teaching methods used does not depend on whether the student is male or female. While descriptive statistics show slight variations in the mean performance scores across gender lines within both the experimental and control groups, these differences are mathematically minor and likely due to chance rather than a systemic pattern.

This finding suggests that the instructional treatments did not interact with the gender of the participants to yield differential academic gains. Consequently, the metacognitive approach can be deemed a gender-fair pedagogical tool that does not disadvantage any learner based on sex. This outcome is consistent with previous research. For instance, Nzeadibe et al. (2019), similarly found no significant interaction effect of teaching strategies and gender on student achievement in geometry. The finding is also in agreement with that of Abdulkari and Ashasim (2025) that there was no significant interaction effect of method and gender on students' means performance scores in reading. The study concluded that there was no significant interaction effect between teaching method (metacognitive vs. traditional) and gender on adjusted post-test reading-comprehension scores. However, these results contradict the conclusions drawn by Ronilo and Maricar (2022), whose meta-analysis indicated that the integration of metacognition in science instruction yields a significantly large, positive effect on learning achievement regardless of gender-based interaction.

Conclusion

The research findings reveal that employing Metacognitive Instructional Strategies significantly enhances secondary school Physics education when compared to conventional teaching methods. Furthermore, this approach proves to be highly inclusive and gender-friendly, ensuring that both male and female students benefit equally from the learning process. These positive results indicate that fostering self-awareness and self-regulation in students' thinking processes leads to a more balanced and effective educational experience.

Recommendations

Based on the findings, the researcher suggests the following:

1. School administrators and supervisors must mandate and oversee the use of Metacognitive Instructional Strategies across all schools to ensure effective delivery of the Physics curriculum.
2. School owners and educational boards should fund professional development—such as seminars and training—to equip Physics educators with modern, metacognitive teaching techniques.
3. Since metacognition boosts academic success in Physics, educators should actively guide students to monitor, evaluate, and regulate their own problem-solving and learning habits.

4. To guarantee successful implementation, schools should continuously monitor and evaluate the daily use of these instructional methods in the classroom.
5. Physics teachers should endeavour to give female and male students equal opportunities in the classroom.

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