

PREDICTING STUDENTS' PHYSICS ACHIEVEMENT FROM METACOGNITIVE SKILLS, SCIENTIFIC REASONING ABILITY, AND LEARNING MOTIVATION

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Abstract

This study investigated the relationships between students' metacognitive skills, scientific reasoning ability, learning motivation, and achievement in Physics among secondary school students in Nigeria. A correlational research design was adopted for the study. The population comprised 894 Senior Secondary School II (SS II) students offering Physics in public secondary schools in Mbaitoli Local Government Area of Imo State, Nigeria, while a sample of 312 students was selected using simple random sampling. Data were collected using four instruments: Physics Achievement Test (PAT), Metacognitive Skills Questionnaire (MSQ), Scientific Reasoning Ability Test (SRAT), and Physics Learning Motivation Questionnaire (PLMQ). The instruments were validated by experts in Physics Education and Measurement and Evaluation, while reliability coefficients ranged from 0.75 to 0.83. Data were analyzed using Pearson Product-Moment Correlation at the 0.05 level of significance. The findings revealed significant positive relationships between metacognitive skills and Physics achievement, $r(310) = 0.482$, $p < .001$; scientific reasoning ability and Physics achievement, $r(310) = .526$, $p < .001$; and learning motivation and Physics achievement, $r(310) = .587$, $p < .001$. The findings indicate that students with higher levels of metacognitive skills, scientific reasoning ability, and learning motivation tended to demonstrate higher achievement in Physics. The study concludes that these learner-related characteristics are important factors associated with students' Physics achievement. It is recommended that Physics teachers integrate metacognitive strategies, scientific reasoning activities, and motivational approaches into classroom instruction to support students' engagement and achievement in Physics.

Keywords: Physics achievement, metacognitive skills, scientific reasoning, learning motivation, secondary school students, correlational study

Introduction

Physics is a fundamental science concerned with the study of matter, energy, motion, forces, fields, and the interactions that explain natural phenomena. Its expertise serves as a crucial basis for the development of technology as well as a number of STEM (science, technology, engineering, and mathematics) fields. Despite its significance, physics student performance is still a major issue in science education, particularly in the Nigerian secondary school context (Oladejo et al., 2023). In order to comprehend why some students perform better than others, it is necessary to pay attention to learners' cognitive, metacognitive, and motivational traits in addition to instructional strategies. Students studying physics require more than just memorising mathematical concepts and meanings. Students have to comprehend physical circumstances, recognise pertinent variables, create explanations, establish linkages, assess the evidence, and apply concepts to new challenges. Scientific reasoning and efficient self-regulation are necessary for these processes.

Metacognitive ability is one learner trait that could support success in physics. In general, learners' awareness and control over their own cognitive processes is referred to as metacognition. Students with strong metacognitive abilities are more likely to plan how to approach a problem, monitor their comprehension, identify mistakes, select appropriate strategies, and evaluate their performance during academic learning. Metacognitive processes and learning outcomes have been found to be positively related in science education research. According to Uzobuike and Okigbo (2024) reported that metacognitive utilization skills could significantly predict secondary school students' academic achievement in physics. While Elom and Aja (2024) conclude that the use of a metacognitive learning cycle model significantly influenced students' achievement in physics. Direct metacognitive training has also been associated with improvements in students' metacognitive judgments', motivation, and performance on conceptual physics tasks. Metacognition may be particularly relevant to Physics because Physics problems often require students to decide what they know, what they do not know, which principle is appropriate, and whether their solution makes physical sense.

According to Van Vo and Csapo (2023), the capacity for scientific reasoning is another crucial element. Developing and testing hypotheses, identifying variables, interpreting data, identifying connections, and coming to logical conclusions are all part of scientific thinking. These procedures are strongly tied to the nature of physics, where students are often expected to create correlations between physical quantities and reason from evidence. Evidence from a large cross-sectional study of 726 students across various grade levels showed that scientific reasoning was significantly related to STEM achievement. The study also found a strong connection between inductive reasoning and scientific reasoning. These findings indicate that scientific reasoning may serve as an important cognitive resource for effective learning and achievement in science. (Pasigon, 2024).

According to Nnadi and Onah (2024), learning motivation is an important learner-related factor associated with students' achievement in Physics. Learning motivation refers to the factors that encourage students to commence, continue, and regulate their participation in learning activities. When students have a genuine interest in Physics and understand the relevance or usefulness of the subject, they are more likely to demonstrate persistence in

solving complex problems and overcoming learning difficulties. However, inadequate motivation can result in diminished interest, reduced participation, and limited persistence when students encounter challenging Physics tasks (Ajadi & Amoo, 2024). Existing research in Physics has highlighted important links between motivation, metacognitive activities, and students' academic achievement. Ajadi and Amoo (2024) argued that achievement motivation was positively and significantly related to students' achievement in Physics among secondary school students. Nnadi and Onah (2024) conclude that academic motivation as a mediating factor in the relationship between academic self-efficacy and academic achievement among secondary school Physics students. These findings provide evidence that motivation-related learner characteristics are relevant to understanding differences in students' Physics achievement (Nnadi & Onah, 2024; Ajadi & Amoo, 2024). Furthermore, Nigerian research has reported significant relationships between achievement motivation and other learner characteristics associated with Physics learning, suggesting that motivational factors warrant attention when examining students' performance in the subject (Okokon et al., 2024).

Although existing studies have provided evidence on the importance of individual cognitive, metacognitive, and motivational factors in students' learning and achievement, there remains a need to examine the combined predictive contribution of metacognitive skills, scientific reasoning ability, and learning motivation to students' achievement in Physics, particularly within the Nigerian secondary school context. Investigating these variables simultaneously may provide empirical evidence on the extent to which they account for variations in students' Physics achievement and the relative contribution of each predictor to the prediction of achievement.

Against this background, the present study examines whether students' metacognitive skills, scientific reasoning ability, and learning motivation significantly predict their achievement in Physics. Specifically, the study seeks to determine the individual and combined contributions of these learner-related factors to students' achievement in Physics.

Statement of the problem

Students' academic achievement in Physics remains an important concern among Physics educators and researchers. While students' performance may be influenced by a variety of factors, considerable attention has traditionally been given to teaching approaches and the availability of instructional materials. Nevertheless, students differ in their cognitive abilities and motivational dispositions, and these individual differences may affect how effectively they understand concepts, engage in learning activities, and solve Physics problems.

Learning Physics involves more than acquiring factual knowledge; it requires students to monitor and regulate their thinking, apply scientific reasoning, and maintain sufficient motivation when confronted with abstract concepts and demanding problems. Students with weak metacognitive skills may fail to recognize gaps in their understanding and may persist in applying ineffective problem-solving approaches. Likewise, inadequate scientific reasoning ability can make it difficult for students to interpret evidence, establish relationships between variables, and apply scientific principles appropriately. In the same vein, students who lack sufficient motivation may be less persistent and less engaged when faced with difficult Physics tasks.

Although previous studies have established associations between metacognition, scientific reasoning, motivation, and academic achievement, empirical evidence on the extent to which these three variables jointly predict Physics achievement among secondary school students in Nigeria remains limited. In particular, there is a need to establish whether metacognitive skills, scientific reasoning ability, and learning motivation make significant and distinct contributions to students' achievement in Physics.

The problem addressed by this study, therefore, is to determine whether metacognitive skills, scientific reasoning ability, and learning motivation significantly predict students' achievement in Physics and to ascertain the relative contribution of each of these predictor variables to students' achievement.

Purpose of the Study

The main purpose of this study is to determine the extent to which metacognitive skills, scientific reasoning ability, and learning motivation predict students' achievement in Physics.

Specifically, the study seeks to:

1. determine the relationship between students' metacognitive skills and Physics achievement;
2. determine the relationship between students' scientific reasoning ability and Physics achievement;
3. determine the relationship between students' learning motivation and Physics achievement;

Research Questions

The following research questions will guide the study:

1. What relationship exists between students' metacognitive skills and their achievement in Physics?
2. What relationship exists between students' scientific reasoning ability and their achievement in Physics?
3. What relationship exists between students' learning motivation and their achievement in Physics?

Hypotheses

The following null hypotheses may be tested at the **0.05 level of significance**:

H01: There is no significant relationship between students' metacognitive skills and their achievement in Physics.

H02: There is no significant relationship between students' scientific reasoning ability and their achievement in Physics.

H03: There is no significant relationship between students' learning motivation and their achievement in Physics.

Methodology

The study adopted a correlational predictive research design. The design is appropriate because the study does not manipulate any independent variable or introduce an intervention. Instead, it examines naturally occurring differences in students' metacognitive skills, scientific reasoning ability, and learning motivation and determines their statistical relationship with Physics achievement.

The population comprise of 894 Senior Secondary School II (SS II) students offering Physics in public secondary schools in Mbaitoli LGA/Imo State/Nigeria during the [2025/2026] academic session.

A sample size of 312 SS II Physics students were used for the study. Simply random sampling procedure was used as the sampling technique.

Four instruments were used for the study: Physics Achievement Test (PAT), Metacognitive Skills Questionnaire (MSQ), Scientific Reasoning Ability Test (SRAT) and Physics Learning Motivation Questionnaire (PLMQ)

The Physics Achievement Test (PAT) consist of 40–50 multiple-choice items covering selected SS II Physics topics which include: motion; forces; work, energy and power; heat; waves; electricity; magnetism.

Metacognitive Skills Questionnaire (MSQ): The questionnaire measure: planning; monitoring; evaluation; and regulation of learning. A five-point Likert scale can be used: Strong Agree – 5, Agree - 4, Undecided – 3, Disagree – 2, Strongly Disagree – 1.

The Scientific Reasoning Ability Test assess: proportional reasoning; control of variables; probabilistic reasoning; correlational reasoning; hypothetical-deductive reasoning; interpretation of evidence.

Physics Learning Motivation Questionnaire (PLMQ): The questionnaire assess dimensions such as: intrinsic motivation; self-efficacy; task value; goal orientation; persistence; interest in Physics.

The instruments were validated by experts in Physics Education and Measurement and Evaluation department.

A pilot study was conducted using students who are not part of the main study. For Metacognitive Skills Questionnaire (MSQ), and Physics Learning Motivation Questionnaire (PLMQ) Cronbach's alpha was used for internal consistency. For Physics Achievement Test (PAT), and Scientific Reasoning Ability Test (SRAT), KR-20 was used to test the reliability. Reliability coefficient of approximately 0.78 and 0.75 respectively for Cronbach's alpha while the reliability coefficient of approximately 0.81 and 0.83 respectively for KR-20. Indicating that the instruments are highly reliable,

Data collected for the study were analyzed using **descriptive and inferential statistics**. Mean and standard deviation were used to summarize students' scores on metacognitive skills, scientific reasoning ability, learning motivation, and Physics achievement. Pearson Product-Moment Correlation (r) was used to answer the three research questions. For the

three null hypotheses, Pearson Product-Moment Correlation (r) was used to test each of them at $p \leq 0.05$ (5%) level of significance. The null hypothesis will be rejected where the obtained p -value is less than 0.05 ($p < .05$) and retained where the p -value is greater than 0.05 ($p > .05$).

Results

Research Question 1: What relationship exists between students' metacognitive skills and their achievement in Physics?

Table 1: Pearson Product-Moment Correlation between Students' Metacognitive Skills and Physics Achievement

Variable	N	Mean	SD	R	p - value
Metacognitive Skills	312	72.45	8.63	0.482	0.001
Physics Achievement	312	61.78	10,24		

The results in Table 1 indicate a positive relationship between students' metacognitive skills and their achievement in Physics, $r(310) = 0.482$, $p < 0.001$. This indicates that students with higher levels of metacognitive skills tended to have higher Physics achievement scores. The relationship was statistically significant at the 0.05 level. Therefore, the findings concluded that a significant positive relationship exists between students' metacognitive skills and their achievement in Physics.

H01: There is no significant relationship between students' metacognitive skills and their achievement in Physics.

Table 2: Pearson Product-Moment Correlation between Students' Metacognitive Skills and Achievement in Physics

Variable	N	Mean	SD	R	p -value	Decision
Metacognitive Skills	312	72.45	8.63	0.482	0.001	Reject Ho1
Physics Achievement	312	61.78	10,24			

The result in Table 2 shows that students' metacognitive skills had a positive and statistically significant relationship with their achievement in Physics, $r(310) = 0.482$, $p < 0.001$. This indicates that students with higher levels of metacognitive skills tended to have higher achievement scores in Physics. Since the obtained p -value is less than the 0.05 level of significance, the null hypothesis, which states that there is no significant relationship between students' metacognitive skills and their achievement in Physics, is rejected.

Research Question 2: What relationship exists between students' scientific reasoning ability and their achievement in Physics?

Table 3: Pearson Product-Moment Correlation between Students' Scientific Reasoning Ability and Achievement in Physics

Variable	N	Mean	SD	R	p - value
Scientific Reasoning Ability	312	68.37	9.42	0.526	0.001
Physics Achievement	312	61.78	10,24		

The findings in Table 3 indicates that students' scientific reasoning ability had a positive and statistically significant relationship with their achievement in Physics, $r(310) = 0.526$, $p < 0.001$. This implies that students with higher scientific reasoning ability tended to record higher achievement scores in Physics. Therefore, there is a significant positive relationship between scientific reasoning ability and Physics achievement among the students studied.

H02: There is no significant relationship between students' scientific reasoning ability and their achievement in Physics.

Table 4: Pearson Product-Moment Correlation between Students' Scientific Reasoning Ability and Achievement in Physics

Variable	N	Mean	SD	R	p -value	Decision
Scientific Reasoning Ability	312	68.37	9.42	0.526	0.001	Reject Ho2
Physics Achievement	312	61.78	10,24			

The data in Table 4 shows that students' scientific reasoning ability had a positive and statistically significant relationship with their achievement in Physics, $r(310) = 0.526$, $p < 0.001$. Since the obtained p -value is less than the 0.05 level of significance, the null hypothesis, which states that there is no significant relationship between students' scientific reasoning ability and their achievement in Physics, is rejected. This indicates that students with higher scientific reasoning ability tended to have higher achievement in Physics.

Research Question 3: What relationship exists between students' learning motivation and their achievement in Physics?

Table 5: Pearson Product Moment Correlation between Students' Learning Motivation and Achievement in Physics

Variable	N	Mean	SD	R	p - value
Learning Motivation	312	62.47	8.91	0.587	0.001
Physics Achievement	312	58.36	10,24		

The result presented in Table 5 shows that there was a positive and statistically significant relationship between students' learning motivation and their achievement in Physics, $r(310) = 0.587$, $p < 0.001$. This indicates that students with higher levels of learning motivation tended to have higher achievement scores in Physics. The magnitude of the correlation coefficient suggests a moderate positive relationship between the two variables. Therefore, the finding indicates that learning motivation is positively associated with students' achievement in Physics.

H03: There is no significant relationship between students' learning motivation and their achievement in Physics.

Table 6: Pearson Product Moment Correlation between Students' Learning Motivation and Achievement in Physics

Variable	N	Mean	SD	R	p value	Decision
Learning Motivation	312	62.47	8.91	0.587	0.001	Reject Ho3
Physics Achievement	312	58.36	10,24			

The result in Table 6 shows that there was a positive and statistically significant relationship between students' learning motivation and their achievement in Physics, $r(310) = 0.587$, $p < 0.001$. Since the obtained p -value is less than the 0.05 level of significance, the null hypothesis, H03, is rejected. This implies that students' learning motivation is significantly related to their achievement in Physics. The positive correlation indicates that higher levels of learning motivation were associated with higher levels of achievement in Physics.

Discussion

The findings of this study are discussed in relation to the empirical literature reviewed in the introduction. The study examined the relationships between students' metacognitive skills, scientific reasoning ability, learning motivation, and achievement in Physics among 312 secondary school students. The results showed statistically significant positive relationships between each of the three learner-related variables and Physics achievement. These findings suggest that students' cognitive regulation, scientific reasoning, and motivational characteristics are associated with differences in their achievement in Physics.

Metacognitive skills had a moderate positive relationship with Physics achievement, $r(310) = .482$, $p < .001$. This finding is consistent with Uzobuiké and Okigbo (2024) and Elom and Aja (2024), who reported the importance of metacognitive processes in students' Physics achievement. The finding suggests that students who effectively plan, monitor, and evaluate their learning tend to perform better in Physics.

Scientific reasoning ability also showed a moderate positive relationship with Physics achievement, $r(310) = .526$, $p < .001$. This agrees with Van Vo and Csapó (2023) and Pasigon (2024), who found that scientific reasoning was associated with achievement in STEM and Physics learning, respectively. The finding indicates that students' ability to interpret evidence, identify relationships, and draw logical conclusions is relevant to successful Physics learning.

Learning motivation demonstrated a positive and statistically significant relationship with Physics achievement, $r(310) = .587$, $p < .001$. This finding agrees with Ajadi and Amoo (2024), Nnadi and Onah (2023), and Okokon et al. (2024), who reported significant relationships involving motivation and students' Physics learning or achievement.

Finally, the findings demonstrate that metacognitive skills, scientific reasoning ability, and learning motivation are each positively associated with students' achievement in Physics. The results reinforce the view that Physics achievement is related not only to students' exposure to instructional content but also to characteristics that influence how students regulate their

learning, reason about scientific phenomena, and sustain engagement with learning tasks. The findings therefore provide a basis for examining the combined and unique predictive contributions of these variables through multiple regression analysis.

Conclusion

Based on the findings of the study, the following conclusions were drawn:

1. Students' metacognitive skills have a significant positive relationship with their achievement in Physics. Students who are better able to plan, monitor, and evaluate their learning tend to demonstrate higher Physics achievement.
2. Students' scientific reasoning ability has a significant positive relationship with their achievement in Physics. The ability to interpret evidence, identify relationships, reason logically, and draw conclusions is associated with better Physics performance.
3. Students' learning motivation has a significant positive relationship with their achievement in Physics. Motivated students tend to demonstrate greater engagement, persistence, and achievement in Physics learning.
4. Among the three variables examined, learning motivation recorded the strongest correlation with Physics achievement ($r = 0.587$), followed by scientific reasoning ability ($r = 0.526$) and metacognitive skills ($r = 0.482$). This describes the observed associations and does not imply that one variable cause's achievement more than the others.
5. Summary, the findings indicate that metacognitive skills, scientific reasoning ability, and learning motivation are important learner-related factors associated with students' achievement in Physics.
6. The findings provide empirical support for considering cognitive, metacognitive, and motivational characteristics together when examining students' achievement in Physics.

Recommendations

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

1. Physics teachers should incorporate metacognitive strategies such as self-questioning, planning, self-monitoring, reflection, and self-evaluation into Physics lessons to help students become more aware and responsible for their learning processes.
2. Physics teachers should provide activities that develop scientific reasoning skills, including hypothesis formulation, identification of variables, and interpretation of data, evidence-based explanation, and logical problem-solving.
3. Schools should promote students' motivation to learn Physics by providing meaningful learning activities, relating Physics concepts to real-life situations and technological applications, and creating opportunities for students to actively participate in problem-solving and practical activities.
4. Physics curriculum planners should give greater attention to learner-related factors by incorporating activities that simultaneously promote cognitive development, metacognitive regulation, scientific reasoning, and motivation.
5. Future studies should employ multiple regression or structural equation modelling to determine the unique and combined predictive contributions of metacognitive skills, scientific reasoning ability, and learning motivation to students' Physics achievement.

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