Science self-efficacy and meta-variables as correlates of academic performance of students in biology

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ABSTRACT

This study examined the relationship between science self-efficacy, meta-variables (meta-awareness, meta-regulation, meta-monitoring, and meta-evaluation), and students' academic performance in Biology among secondary school students in Kogi East, Nigeria. Six research questions and six null hypotheses were tested at a 0.05 significance level. The study adopted a correlational design. The population included 9,001 Senior Secondary Two students, with a sample of 382 selected from five schools using a multistage sampling technique. Data were collected using the researcher-designed Biology Performance Test (BPT), Biology Self-Efficacy Scale (BSES), and Biology Meta-Variable Scale (BMVS). These instruments were validated by experts in science education, measurement, and evaluation, and were trial tested. The reliability coefficients were 0.84 (BPT), 0.89 (BMVS), and 0.82 (BSES). Regression analysis addressed research questions, while ANOVA tested the hypotheses. Results indicated a strong correlation ($r = 0.777$, $R^2 = 0.604$) between science self-efficacy and biology performance. Meta-awareness ($r = 0.650$, $R^2 = 0.423$), meta-regulation ($r = 0.677$, $R^2 = 0.458$), meta-monitoring ($r = 0.511$, $R^2 = 0.261$), and meta-evaluation ($r = 0.571$, $R^2 = 0.326$) correlated significantly with biology performance.The combined influence of science self-efficacy and meta-variables on Biology performance ($r = 0.510$, $R^2 = 0.260$) was also significant. Findings suggest that higher science self-efficacy enhances academic performance in Biology. Meta-variables play a crucial role in shaping students' learning outcomes. The study recommends improving Biology instruction through active engagement methods such as problem-solving tasks, group discussions, and real-world applications. Encouraging scientific investigations along with inquiry-based learning can further enhance students' performance in Biology.

Keywords: *Biology, meta-awareness, meta-variables, meta-monitoring, and meta-evaluation, meta-regulation, science self-efficacy, students' academic performance.*

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Highlights of this paper

- This study investigated the connection between students' confidence in their science abilities (self-efficacy), their awareness of and control over their learning strategies (metacognitive variables), and their academic performance in biology among Nigerian secondary school students.
- By using surveys, researchers found a significant positive correlation among these factors, indicating that higher self-efficacy and improved metacognitive skills contribute to better outcomes.
- Biology grades highlight the importance of active learning approaches in enhancing students' biological knowledge and engagement.

1. INTRODUCTION

The importance of Biology in the school curriculum cannot be overstated. As a subject that focuses on the processes that determine the existence of life, it is appropriate for secondary school students to understand these processes and their application in real-life situations. Green (2022) emphasized that Biology concerns living organisms and their vital processes. These vital processes refer to the stages that cells undergo and the developmental stages in animals (Zoology). Biology also includes the study of organism structure (Morphology) and function (Physiology) (Green, 2022). As a discipline that educates learners about the presence of life forms, Biology is directly relevant to students' knowledge. Therefore, it is essential to help learners understand key concepts and their practical implications.

Like other science subjects in the school curriculum, the academic performance of students in Biology is not just a point of concern for teachers but also for the nation at large. Ghumdia and Adams (2017) opine that Biology contributes to the economy of any nation as it is essential for careers in many fields, including medicine, agriculture, agrotechnology, and nursing. A solid foundation in science is therefore necessary for students who intend to pursue careers in these areas. For students aiming to advance their academic pursuits in Arts and Humanities, Biology as a core subject helps them understand key aspects of human life, such as diseases, genetics, pollution, and the functioning of the human body systems (Mwenda & Ndayambaje, 2021). Improving students' academic performance in this field is therefore crucial.

Academic performance, as used in this study, refers to the extent to which the learner understands and attains the set objectives in biology, and this is expressed in grades obtained from tests and examinations. Torres and Rodríguez, in Willcox (2011), give a broader perspective of the term by referring to it as the level of knowledge shown in an area or subject compared to the norms, and it is generally measured using grades. The quality of students' performance is often indicated by numbers, letters of the alphabet, or other sign (Bragdon & Dowler, 2016). This is often done in consideration of regulations from the Federal Ministry of Education or the school (the school may evolve their grading system). Either way, students' performance may be viewed by setting performance standards and comparing them with set objectives or by comparing it with the performance of other students in the same class (Ergen & Kanadlı, 2017).

The academic performance of Nigerian students in Biology has not been impressive over the years. This low performance is documented in the reports of the West Africa Examination Council (WAEC) Chief Examiner from 2013, 2014, 2015, 2016, 2017, and 2018, where only 21%, 35%, 34%, 29%, 30%, and 33% passed with credit or better grades, confirming this trend at the national level. Additionally, data from the National Bureau of Statistics on the performance of students in Biology in public schools across Nigerian states indicate persistent poor performance. For instance, only 47%, 43%, 54%, 47%, 42%, 47%, and 40% of students who sat for the Biology Senior School Certificate Examination (SSCE) conducted by the West African Senior School Certificate Examination (WASSCE) from 2014 to 2022 achieved credit level passes or above in the examination (National Bureau of Statistics, 2023).

The poor performance is also reported by Bichi, Hafiz, and Abdullahi (2017) and Bichi, Ibrahim, and Ibrahim (2019). The gloomy nature of students' academic performance in Biology in the West African Senior School Certificate Examination (WASSCE) was further highlighted by the WAEC Chief Examiner's report in 2021. According to the report, students failed to correctly spell and explain technical terms. They also failed to adhere to guidelines regarding drawings. These are indications of poor academic performance in Biology. These failures could also be linked to students' inability to think critically while reading and writing internal and external examinations.

Self-efficacy is a key psychological construct with significant implications for learning. Bandura (2012) defines self-efficacy as an individual's belief in their ability to carry out behaviors required to achieve specific outcomes essentially, the motivation and confidence to begin, persist, and complete tasks or goals. It encompasses a person's perceived control over their own drive, behavior, and environment. These self-perceptions play a vital role in shaping human experiences, influencing the goals people set, the level of commitment they dedicate to achieving those goals, and the probability of attaining expected performance standards. Within education, self-efficacy is widely recognized as a critical determinant of academic success. Hu, Jiang, and Bi (2022) argue that science self-efficacy is a central factor contributing to students' reluctance to pursue science-related subjects in school. This suggests that learners' academic achievement in science, particularly Biology, can be better understood in relation to their self-efficacy. Earlier scholars (Ballen, Wieman, Salehi, Searle, & Zamudio, 2017; Blotnicky, Franz-Odendaal, French, & Joy, 2018; Caprara et al., 2008) also demonstrated that self-efficacy is one of the variables influencing students' scholastic outcomes.

Ayllón, Alsina, and Colomer (2019), in their exploration of teacher involvement and students' self-efficacy as central elements of academic achievement in higher education revealed that higher self-efficacy strongly predicts better academic performance compared to lower self-efficacy. This underscores a positive correlation between students' scholastic results and their perceived determination and confidence in their learning capacities, particularly in areas such as life sciences and medicine. Similarly, Hayat, Shateri, Amini, and Shokrpour (2020) affirmed that self-efficacy significantly shapes task selection and persistence during task performance. In particular, learners with stronger self-efficacy are more likely to rely on their own abilities to devise solutions and to remain steadfast when facing academic challenges. These findings are supported by studies examining the relationships between self-efficacy, self-regulated learning strategies, and academic achievement. For example, Sadi and Uyar (2013), Achor and Ejeh (2019), and Achor, Zaria, and Achor (2022) reported that self-efficacy and performance serve as predictors of secondary school students' achievement.

The academic attainment of students in science, especially biology, serves as an important measure of a nation's growth. Science generally, and biology in particular, have become indispensable drivers of economic and social advancement, making modern life unimaginable without them (Oyovwi, 2022). Therefore, the need to improve learners' scholastic performance in this domain is urgent. One possible strategy is to examine how science self-efficacy and related meta-variables are connected to biology achievement.

While previous research has considered self-efficacy as an independent predictor of educational outcomes, there is still a limited number of studies assessing its impact on Biology achievement in Nigeria, particularly within Kogi State. Examining the extent to which students have control over their self-efficacy and metacognitive variables to influence their performance is relevant in this work, as it is expected that improvements in both variables could lead to enhanced academic performance and vice versa. This research aims to fill that gap by exploring the connections between science self-efficacy and Biology performance. Understanding these relationships can provide meaningful insights for teachers and policymakers seeking to improve students' success in Biology.

1.1. Statement of the Problem

The academic performance of students in science is always of concern to parents, teachers, and examination boards in Nigeria. This is because science can be seen as the lifeblood of any nation. Biology, as a science subject, is the study of all life forms; as such, students who wish to pursue a career in medicine must first pass this subject at the O-level. Even with the overwhelming importance of Biology, the academic performance of students in this subject has not been impressive in recent years. Students' performance in secondary school Biology has shown a consistent pattern of poor outcomes in both internal and external assessments, including the West African Senior School Certificate Examination (WASSCE). WAEC Chief Examiners have reported this trend; for instance, the performance of Biology students over the years has been poor (West African Examinations Council, 2023). This poor performance raises questions about the factors influencing students' academic performance in Biology, particularly in areas that require critical thinking and higher-order cognitive skills. Could these problems be tied to students' psychological processes of self-efficacy?

Contemporary research has related students' academic performance in the classroom to self-efficacy. An understanding of this concept and its relation to the academic performance of students in Biology could better address the issue of poor academic performance in Biology. It is in line with this premise that the researcher sets out to address the question: how does science self-efficacy correlate with Biology performance among secondary school students in Kogi East Education Zone, Nigeria?

1.2. Research Questions

The following research questions guided the study: What is the relationship between:

1. Science self-efficacy and academic performance of students in biology?
2. Science meta-awareness and academic performance of students in biology?
3. Science metacognitive regulation and academic performance of students in Biology?
4. Science metacognitive monitoring and academic performance of students in Biology?
5. Science metacognitive evaluation and academic performance of students in biology?
6. The combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation, and academic performance of students in biology?

2. REVIEW OF RELATED LITERATURE

Jamil and Mahmud (2019) conducted a quantitative study in the Rompin district of Malaysia aimed at examining the relationship between science self-efficacy and academic achievement among secondary school students. Using a correlational survey design, the study sampled 191 students from four national secondary schools. Data were collected using a structured questionnaire specifically developed to assess students' confidence in their ability to perform science-related tasks. A pilot test established the instrument's reliability, producing a high Cronbach's alpha value of 0.89, which confirmed strong internal consistency. Despite the robust reliability, the Pearson correlation analysis revealed no statistically significant relationship between science self-efficacy and academic achievement ($r = 0.124$, $p = 0.09$). This outcome suggests that in certain contexts, high self-efficacy in science may not necessarily translate into improved academic scores, possibly due to intervening factors such as instructional quality, learning strategies, or external stressors.

Contrastingly, Aurah (2017) reported markedly different results in a study conducted among 2,139 12th-grade (SS2) students in Kenya. Employing a correlational design and guided by three hypotheses, Aurah measured science self-efficacy using the Science Self-Efficacy Scale (SSES) and assessed academic achievement through an 18-item

open-ended Genetics Problem-Solving Test (GPST), which was validated through expert review to ensure face and content validity. The analysis revealed a strong positive correlation between science self-efficacy and achievement in genetics, indicating that students with greater confidence in their science abilities tended to achieve higher scores. Notably, the study also identified significant gender differences, with female students outperforming males in both self-efficacy and academic performance. These findings stand in stark contrast to those of Jamil and Mahmud (2019), implying that cultural, instructional, and demographic contexts may mediate the self-efficacy–achievement link.

In addition to gender and cultural influences, socioeconomic background has also been linked to variations in science self-efficacy. Tan, Gao, Hong, and Song (2023) examined this relationship using data from the 2015 Programme for International Student Assessment (PISA) across the United Arab Emirates, Australia, Austria, Belgium, and Bulgaria. Their large-scale analysis involved 509,182 fifteen-year-old students and 17,678 school principals from 69 countries/regions (Organisation for Economic Co-operation and Development (OECD), 2017). Science self-efficacy was assessed through an Item Response Theory (IRT)-generated measure based on students' confidence in performing eight different science-related tasks, with responses reverse-coded on a four-point scale. The findings indicated a significant positive association between parental socioeconomic status and science self-efficacy, suggesting that students from more advantaged backgrounds are more likely to possess greater confidence in their science abilities. This highlights the role of social and economic capital in shaping learners' beliefs and expectations about their capacity to succeed in science.

While self-efficacy focuses on belief in one's capabilities, metacognitive awareness emphasizes the ability to monitor, control, and regulate one's cognitive processes during learning. Nguyen et al. (2023) investigated the connection between metacognitive awareness and academic performance among 202 undergraduate medical students at Vietnam Military Medical University. Employing a correlational survey design, the study covered participants from first-year to sixth-year levels, including both military and civilian students during the 2020–2021 academic session. The results demonstrated a significant positive relationship between metacognitive awareness and academic performance, suggesting that students who are more aware of and can regulate their learning processes tend to achieve higher academic outcomes.

Similarly, Abdellah (2015) studied 70 pre-service female teachers at Ajman University in the United Arab Emirates to explore the relationships between metacognitive awareness, academic achievement, and teaching performance. Participants were grouped according to academic background, with one group drawn from scientific disciplines such as mathematics, science, and information technology, and the other from non-science disciplines. Using the Metacognitive Awareness Inventory (MAI) developed by Schraw and Dennison (1994), the study reported reliability coefficients of 0.78 for knowledge of cognition, 0.81 for regulation of cognition, and 0.79 for the overall instrument. Findings indicated a positive association between metacognitive awareness and Grade Point Average (GPA), reinforcing the idea that heightened metacognitive skills contribute to superior academic outcomes.

Sawhney and Bansal (2015) further strengthened this line of evidence in a study involving 100 undergraduate students from various colleges in Chandigarh. Using the MAI and students' previous academic records, they found a significant difference in academic performance between students with high and low metacognitive awareness, with those possessing stronger metacognitive skills achieving higher results. Narang and Saini (2013) provided additional confirmation in their study of 240 rural adolescents in Punjab, India, reporting that both knowledge of cognition and regulation of cognition were significantly linked to above-average academic achievement, and that students with high levels of metacognitive regulation consistently performed better than their peers.

At a more detailed level, MacKewn, Depriest, and Donavant (2022) examined how metacognitive knowledge and metacognitive regulation interact and how they relate to study habits. Using the MAI to measure self-regulated learning skills, they found a significant positive relationship between the two dimensions of metacognition. Students with greater awareness of their thinking processes were more inclined to apply effective regulatory strategies, which in turn contributed to stronger academic performance. This finding aligns with the broader consensus that metacognitive abilities underpin successful learning by enabling students to plan, monitor, and adapt their approaches to study.

This study utilizes self-efficacy theory as proposed by Bandura (1977). The theorist asserts that individuals' judgments of their capabilities to organize and execute the courses of action necessary to achieve specific performance outcomes influence their motivation and attitude toward a task. This attitude or motivation can be either negative or positive; it forms the individual's set of beliefs. Furthermore, this set of beliefs, which Bandura refers to as a 'set of beliefs,' significantly influences future behavior in various situations. The self-efficacy theory is relevant to the present study, particularly concerning science self-efficacy, which is a crucial variable explained by this theory. According to the theory, for secondary-level students to excel, they must develop positive self-efficacy beliefs. Such beliefs motivate students to remain determined and focused on success, even when certain aspects of the subject appear challenging. This determination is derived from four sources: mastery experiences, vicarious experiences, social experiences, and emotional or psychological states of the student. These sources have implications for both Biology students and teachers. Mastery experiences involve the student's ability to perform individual activities aimed at enhancing their self-efficacy and understanding of Biology concepts and practical skills. This motivation encourages students to inquire into difficult aspects of the subject, often through repeated efforts to ensure proper understanding. It is important to note that mastery experiences primarily involve students' efforts to understand independently, with minimal or no assistance from the teacher.

The feedback (social experiences) the student receives from the teacher in the class is also vital in determining how he or she develops the necessary self-efficacy beliefs that will aid in learning Chemistry. By implication, positive feedback enhances self-efficacy, while consistently negative feedback may diminish it.

3. METHODS

This research employed a correlational design, which was intended to determine the association that exists between two or more variables (Emaikwu, 2015). As noted by Emaikwu (2015), correlational studies typically describe both the direction and strength of the relationship among the variables under investigation. In such a design, the researcher does not alter or influence any of the variables being examined. For the analysis of the data, the design utilized a specific statistical measure referred to as the correlation coefficient.

The choice of this design was informed by the nature of the present investigation and the procedures required for data collection. It was deemed the most suitable approach since the study aimed to address the research questions and evaluate the hypotheses concerning the potential association between measures of self-efficacy and academic achievement.

3.1. Population, Sample and Sampling

The population of this study consisted of all the 9001 Senior Secondary Two (SS2) students from the 111 public schools in Kogi-East Education Zone (Kogi State Ministry of Education, 2023). The researcher used SS2 students who offer Biology because any remediation at this level could help this category of students in external

examinations, especially those conducted by the West African Examination Council and the National Examination Council.

The sample size for this study was 382 SS2 students selected from a population of 9001 using (Yamane, 1967) formula for determining sample size. The schools sampled, from which the 382 students were also selected, included St. Charles College, Ankpa; Enjema Community Grammar School Ofugo; Community Secondary School Ojoku; Government Science Secondary School Dekina; and Our Lady of Schools, Anyigba. The researcher employed a multi-stage sampling technique to ensure proper distribution of the sample size. This approach was necessary because different sampling techniques were used at various stages. Initially, a purposive sampling technique was used to select three local government areas out of the nine, and five schools from these areas.

At the second stage, the researcher adopted a proportionate stratified random sampling technique to select the samples from each school. The proportionate stratified random technique makes it possible for the researcher to ensure that the sample is commensurate with the number of students in the schools.

Finally, the researcher used a simple random sampling technique to select individual participants in the study. The hat and draw procedure was particularly used. The researcher proceeded by writing "YES" and "NO" on a piece of paper. Students who picked YES were selected for the study, while those who picked NO were not selected. The researcher continued this until he arrived at 382.

3.2. Instrumentation

The General Self-Efficacy Scale Sherer et al. (1982) consists of 23 items rated on a 5-point Likert scale, where 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, and 5=Strongly Agree. The current version has been modified to align with the specific goals of this study. Additionally, the Biology Self-Efficacy Scale comprises 30 items. The response pattern was adjusted to a four-point Likert scale, with 1=Strongly Disagree, 2=Disagree, 3=Agree, and 4=Strongly Agree, to offer respondents a broader range of options. Scoring was reversed for negative statements. The total score ranges from 30 to 120, with higher scores indicating greater self-efficacy.

3.3. Validation and Reliability of Instruments

The instruments for data collection for this study were validated by three experts in science education and an expert in measurement and evaluation, all from the Faculty of Education, Benue State University, Makurdi. The experts reviewed and validated the research instruments to ensure they meet the necessary standards for reliability, validity, and relevance to the study's objectives. They also carried out face and content validation of the BSES.

The validators commented and suggested that the number of items in the instrument - Biology Self-Efficacy Scale (BSES) - should be reduced. Other observations were related to semantics. The researcher ensured that the number of items was aligned with the objective of the study. Items 5 and 28 of BSES were discarded for the same reason. The suggestions from the experts' reports were adopted to improve the instruments.

The instrument was subjected to trial testing on 30 students in Demonstration Secondary School, Ankpa, a school that is within the area of the study but outside the schools sampled for the study. The trial testing enabled the researcher to determine the internal consistency of the test.

Scores obtained from the test were used to analyze the reliability coefficient of the instrument. Kuder-Richardson formula (K-R21) was used for Biology Performance. Cronbach's Alpha was used to establish the reliability of the Biology Self-Efficacy Scale because it is suitable for scores using scales, and also because its focus is mainly on internal consistency. The reliability of the Biology Self-Efficacy Scale (BSES) yielded a coefficient of 0.82.

Item analysis was carried out on the Biology Self-Efficacy Scale (BSES) to establish its construct validity. Construct validation was performed for the Biology Self-Efficacy Scale (BSES) using factor analysis. This was based on the extraction method of principal component analysis. The rotation method of Varimax with Kaiser Normalization was used. The reason for choosing construct validation is that students' ability to think comprises several almost uncorrelated functioning parts known as factors, which can be identified through a technique called factor analysis.

The item selection was conducted using the rotated component matrix. Items with factor loadings of 0.35 and above on any of the factors were identified and included in the final version of the instruments. Items that failed to load at least 0.35 were discarded. Consequently, items 5 and 28, which did not meet the loading threshold, were removed from the BSES.

3.4. Method of Data Collection and Analysis

A letter of introduction was presented from the Department of Science and Mathematics Education, Benue State University, Makurdi, to the school authority seeking permission to conduct the exercise in the school. This was done before the actual exercise of administering the instruments. Five teachers who teach Biology in the sampled schools served as research assistants. The test instruments were administered to the students, after which the questionnaires were subsequently administered. The researcher briefed the assistants on how to administer the instruments. First, BSES was administered, which lasted for one hour. The instruments were administered over two days in each school. The data collection process lasted for two days.

The research questions were answered using regression analysis. This method measures the strength and direction of the relationship between pairs of continuous variables and helps in identifying whether these variables are associated (positively or negatively) and the degree of that association.

Regression ANOVA was used to test the hypotheses at a 0.05 significance level. Regression analysis went a step further by assessing the predictive power of science self-efficacy on student performance. By testing the hypotheses, regression analysis revealed how well this independent variable (self-efficacy) explains the variance in the dependent variable (performance). This method not only confirms correlations but also helps to understand which factors are stronger predictors, making it useful for practical applications in educational strategies.

Table 1. Regression analysis of the relationship between science self-efficacy and academic performance of students in biology.

Model	R	R square	Adjusted R square	Std. error of the estimate
1	0.777	0.604	0.600	12.606

4. RESULTS

4.1. Relationship between Science Self-Efficacy and Academic Performance of Students in Biology

Table 1 presents the regression outcome evaluating the linkage between science self-efficacy and learners' achievement in Biology. The table illustrates the linear regression framework connecting science self-efficacy with achievement in Biology. The analysis shows a correlation value of 0.777 and a coefficient of determination (R^2) of 0.604. This implies that science self-efficacy accounts for 60.4% of the variance in students' performance in Biology. Thus, the magnitude of the relationship between science self-efficacy and Biology achievement is 0.777.

Table 2. ANOVA of relationship between science self-efficacy and academic performance of students in biology.

Model		Sum of squares	Df	Mean square	F	Sig.
1	Regression	345.719	1	345.719	2.176	0.041
	Residual	57681.706	363	158.903		
	Total	58027.425	364			

Table 2 reveals that $F(1, 364) = 2.176$; $p = 0.041 < 0.05$. Thus, the null hypothesis is rejected. This indicates that there is a significant relationship between science self-efficacy and academic performance of students in Biology. Therefore, based on evidence from data analysis, there is a significant correlation between science self-efficacy and students' performance in Biology.

Table 3. Regression analysis of the relationship between science meta-awareness and academic performance of students in biology.

Model	R	R square	Adjusted R square	Std. error of the estimate
1	0.650	0.423	0.420	12.617

4.2. Relationship between Science Meta-Awareness and Academic Performance of Students in Biology

Table 3 outlines the regression between science meta-awareness and students' scholastic achievement in Biology. The table illustrates the linear regression framework connecting science meta-awareness with academic outcomes in Biology. The findings indicate a correlation value of 0.650 and a coefficient of 0.423. This signifies that science meta-awareness explains 42.3% of the variance in students' attainment in Biology. Hence, the magnitude of the relationship between science meta-awareness and academic performance in Biology is 0.650.

Table 4. ANOVA of relationship between science meta-awareness and academic performance of students in biology.

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	241.879	1	241.879	1.519	0.019
	Residual	57785.546	363	159.189		
	Total	58027.425	364			

Table 4 reveals that $F(1,364) = 1.159$; $p = 0.019 < 0.05$. Thus, the null hypothesis is rejected. This implies that there is a significant association between science meta-awareness and the academic performance of students in Biology. Based on evidence from data analysis, there is a significant connection between science meta-awareness and students' academic performance in Biology.

Table 5. Regression analysis of relationship between science metacognitive regulation and academic performance of students in biology.

Model	R	R square	Adjusted R square	Std. error of the estimate
1	0.677	0.458	0.450	12.605

4.3. Relationship between Science Metacognitive Regulation and Academic Performance of Students in Biology

Table 5 shows the regression of the relationship between science metacognitive regulation and academic performance of students in Biology. The table reveals the linear regression model of science metacognitive regulation and academic performance of students in Biology. The analysis shows that the association between science metacognitive regulation and the academic performance of students in Biology is 0.677, with a coefficient of determination of 0.458. This implies that 45.8 percent of the performance of students in Biology is accounted for by their science metacognitive regulation. Therefore, the relationship between science metacognitive regulation and academic performance of students in Biology is 0.677.

Table 6. ANOVA of relationship between science metacognitive regulation and academic performance of students in biology.

Model		Sum of squares	Df	Mean square	F	Sig.
1	Regression	347.399	1	347.399	2.186	0.040
	Residual	57680.025	363	158.898		
	Total	58027.425	364			

Table 6 reveals that $F(1,364) = 2.186$; $p = 0.047 < 0.05$. Thus, the null hypothesis is rejected. This indicates that there is a significant association between science metacognitive regulation and students' performance in Biology. Based on data analysis, there is a significant relationship between science metacognitive regulation and students' academic performance in Biology.

Table 7. Regression analysis of relationship between science metacognitive monitoring and academic performance of students in biology.

Model	R	R square	Adjusted R square	Std. error of the estimate
1	0.511	0.261	0.260	12.643

4.4. Relationship between Science Metacognitive Monitoring and Academic Performance of Students in Biology

Table 7 presents the regression analysis assessing the link between science metacognitive monitoring and students' academic attainment in Biology. The table displays the linear regression model connecting science metacognitive monitoring with performance in Biology. The analysis reveals a correlation coefficient of 0.511 and a coefficient of determination (R^2) of 0.261. This indicates that science metacognitive monitoring explains 26.1% of the variability in students' achievement in Biology. Thus, the strength of the association between science metacognitive monitoring and academic performance in Biology is 0.511.

Table 8. ANOVA of the relationship between science metacognitive monitoring and academic performance of students in biology.

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	6.653	1	6.653	0.042	0.038
	Residual	58020.772	363	159.837		
	Total	58027.425	364			

Table 8 reveals that $F(1,507) = 0.920$; $p = 0.038 < 0.05$. Thus, the hypothesis is rejected. This infers that there is a significant relationship between science metacognitive monitoring and the performance of students in Biology. Based on evidence from data analysis, there is a significant relationship between science metacognitive monitoring and the academic performance of students in Biology.

Table 9. Regression analysis of relationship between science metacognitive evaluation and academic performance of students in biology.

Model	R	R square	Adjusted R square	Std. error of the estimate
1	0.571	0.326	0.320	12.643

4.5. Relationship between Science Metacognitive Evaluation and the Academic Performance of Students in Biology

Table 9 shows the regression of the relationship between science metacognitive evaluation and the performance of students in Biology. The table reveals the linear regression model of science metacognitive evaluation and academic performance of students in Biology. The analysis shows that the correlation between science metacognitive evaluation and the performance of students in Biology is 0.571, with a coefficient of 0.326. This implies that 32.6 percent of the academic performance of students in Biology is accounted for by their science

metacognitive evaluation. Therefore, the relationship between science metacognitive evaluation and academic performance of students in Biology is 0.571.

Table 10. Regression analysis of relationship between science metacognitive evaluation and academic performance of students in biology.

Model		Sum of squares	Df	Mean square	F	Sig.
1	Regression	27.715	1	27.715	0.173	0.036
	Residual	58027.373	363	159.855		
	Total	58027.425	364			

Table 10 reveals that $F(1,364) = 0.173$; $p = 0.036 < 0.05$. Thus, the hypothesis is rejected. This implies that there is a significant relationship between science metacognitive evaluation and the performance of students in Biology. Therefore, based on evidence from data analysis, there is a significant relationship between science metacognitive evaluation and the academic performance of students in Biology.

Table 11. Regression analysis of relationship between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and academic performance of students in biology.

Model	R	R square	Adjusted R square	Std. error of the estimate
5	0.510	0.260	0.260	12.637

4.6. Relationship Among Science Self-Efficacy, Meta-Awareness, Metacognitive Regulation, Metacognitive Monitoring, Metacognitive Evaluation and Academic Performance of Students in Biology

Table 11 shows the regression of the joint contribution of a combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, and metacognitive evaluation to the academic performance of students in Biology. The table reveals the linear regression model of a combination of these variables and the performance of students in Biology. The analysis indicates that the correlation between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation, and academic performance of students in Biology is 0.510, with a coefficient of determination of 0.260. This implies that 26.0 percent of the variance in students' academic performance in Biology is explained by the joint contribution of these variables. Therefore, the relationship between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation, and academic performance of students in Biology is represented by a correlation coefficient of 0.510.

Table 12. Stepwise multiple regression analysis of the relationship between the combination of meta-variables and the academic performance of students in biology.

Model		Sum of squares	Df	Mean square	F	Sig.
5	Regression	698.478	5	139.696	0.875	0.048
	Residual	57328.947	359	159.691		
	Total	58027.425	364			

Table 12 reveals that $F(5, 364) = 0.875$; $p = 0.048 < 0.05$. Thus, the hypothesis is rejected. This implies that there is a significant relationship between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation, and performance of students in Biology. Therefore, based on evidence from data analysis, a significant relationship exists between these variables and the academic performance of students in Biology.

Table 13. Contributions of meta-variables in the overall relationship with students' performance in biology.

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
5	(Constant)	50.915	10.214		4.985	0.000
	Science self-efficacy	-2.950	2.190	0.071	-1.347	0.179
	Science meta-awareness	3.894	7.353	0.087	0.530	0.051
	Science metacognitive regulation	-6.851	7.288	0.154	-0.940	0.034
	Science metacognitive monitoring	-0.880	3.549	0.023	-0.248	0.804
	Science metacognitive evaluation	1.346	3.625	0.034	0.371	0.711

Table 13 shows a standard multiple regression analysis of the meta-variables and performance of students in Biology. The table indicates that Science self-efficacy has a predictive power of 0.071, contributing 7.1 percent to the academic performance of students in Biology, with a P-value of 0.71, which is greater than 0.05. This suggests that Science self-efficacy does not significantly contribute to students' performance in Biology. Science meta-awareness has a predictive power of 0.087, contributing 8.7 percent, with a P-value of 0.51, also greater than 0.05, indicating no significant contribution. Science metacognitive regulation has a predictive power of 0.154, contributing 15.4 percent, with a P-value of 0.031, which is less than 0.05, signifying a significant contribution to students' academic performance in Biology. Science metacognitive monitoring has a predictive power of 0.023, contributing 2.3 percent, with a P-value of 0.0804, greater than 0.05, indicating no significant contribution. Science metacognitive evaluation has a predictive power of 0.034, contributing 3.4 percent, with a P-value of 0.771, also greater than 0.05, indicating no significant contribution. The order of contributions of the meta-variables to the significance of the regression with students' performance in Biology is: Science metacognitive monitoring (2.3%), Science metacognitive evaluation (3.4%), Science self-efficacy (7.1%), Science meta-awareness (8.7%), and Science metacognitive regulation (15.4%).

5. DISCUSSION OF FINDINGS

The results derived from this investigation are presented and interpreted in this section. The study examined the extent to which science self-efficacy and selected meta-cognitive constructs are associated with performance in biology and critical thinking skills among senior secondary school learners in the Kogi East Education Zone, Nigeria. The discussion is organized in line with the research questions and the corresponding hypotheses that framed the study.

5.1. Link between Science Self-Efficacy and Academic Performance in Biology

The results demonstrated a statistically significant association between science self-efficacy and learners' academic achievement in Biology, implying that self-efficacy serves as a pivotal predictor of success in the subject. This finding is consistent with the work of Oyuga, Raburu, and Aloka (2019), who observed that students with stronger self-efficacy beliefs generally attain superior academic outcomes compared to peers with lower self-confidence. Likewise, it aligns with Aurah (2017), who documented a robust positive relationship between science self-efficacy and academic achievement, alongside notable gender variations, where female students surpassed males in both self-efficacy and achievement measures. Conversely, the present finding contradicts the work of Gloudemans, Schalk, and Reynaert (2013), who detected no meaningful link between educational level and self-efficacy beliefs, and also differs from Jamil and Mahmud (2019), who reported an absence of a significant connection between self-efficacy and academic performance among Malaysian secondary school learners.

The outcomes of this study reinforce the perspective that strong self-efficacy beliefs are instrumental in boosting both scholastic success and personal well-being. Learners with high self-efficacy typically view demanding academic tasks as opportunities to grow rather than threats to avoid. Such individuals exhibit intrinsic motivation, set challenging goals, commit to those goals, and persist despite setbacks or failure. They are also more likely to redouble their efforts in the face of difficulty, quickly restore confidence after a setback, and interpret failure as a temporary gap in knowledge or skill, which are deficiencies they believe can be remedied through further learning. This adaptive mindset likely explains the substantial positive link observed between science self-efficacy and biology performance.

5.2. Connection between Science Meta-Awareness and Academic Performance in Biology

The findings indicated a significant correlation between science metacognitive awareness and students' achievement in Biology, highlighting meta-awareness as a vital contributor to academic attainment. This is in harmony with prior research by Abdellah (2015), Achor et al. (2022), and Abd-Ellah et al. (2017), who found positive associations between metacognitive awareness and grade point averages among pre-service female teachers. It also mirrors the results of Sawhney and Bansal (2015), who identified notable differences in achievement between undergraduates with high versus low meta-awareness. Similarly, the study supports Khairinaa, Wahyuningsih, and Khasanah (2023), who linked meta-awareness with better learning outcomes in science, and Nguyen et al. (2023), who established that meta-awareness significantly predicts medical students' academic results.

Meta-awareness represents a higher-order cognitive ability involving conscious insight into and regulation of one's thought processes, including planning, monitoring, and ongoing evaluation of learning tasks. It also entails understanding the factors that influence learning, familiarity with effective strategies, and the skill to select and apply appropriate methods for greater self-control and self-management. Through meta-awareness, students gain clarity on their strengths and limitations, enabling them to choose learning approaches that best support their academic progress. Such self-regulated learning capabilities likely underpin the significant association found between meta-awareness and biology performance.

5.3. Relationship between Science Metacognitive Regulation and Academic Performance in Biology

The results revealed a meaningful relationship between science metacognitive regulation and learners' performance in Biology, identifying metacognitive regulation as a key driver of academic success. This outcome aligns with Achor et al. (2022), who documented a positive connection between metacognitive regulation and achievement, and echoes MacKewn et al. (2022), who observed that students with greater awareness of their metacognitive knowledge tend to implement more effective regulation strategies, thereby improving their academic outcomes.

Metacognitive regulation involves overseeing, directing, and adjusting one's learning strategies in response to ongoing experiences. Learners with strong regulation skills can assess their comprehension, recognize areas of difficulty, and modify their study methods accordingly. This ability to manage learning strategically allows them to prioritize weak areas, maximize time efficiency, and adopt the most productive techniques. Such adaptive, reflective behaviors likely account for the positive link between science metacognitive regulation and biology performance.

5.4. Association between Science Metacognitive Monitoring and Academic Performance in Biology

The study showed a significant connection between science metacognitive monitoring and learners' achievement in Biology, signifying that monitoring skills play an important role in academic success. This agrees

with Nietfeld, Cao, and Osborne (2005), who found that effective metacognitive monitoring is generally linked with enhanced academic outcomes.

Metacognitive monitoring heightens students' awareness of the factors that hinder or promote learning. It enables learners to identify their strengths and weaknesses as readers, writers, problem-solvers, test-takers, and group participants. It also involves recognizing the boundaries of one's current knowledge and determining strategies to expand it. Students who understand their own capabilities can more purposefully track their progress, assess their preparedness for specific tasks, and adjust their learning strategies as needed. This active engagement in the learning process may explain the significant association found between metacognitive monitoring and biology achievement.

5.5. Relationship between Science Metacognitive Evaluation and Academic Performance in Biology

The findings established a notable relationship between science metacognitive evaluation and learners' performance in Biology, underscoring evaluation skills as a meaningful predictor of academic achievement. Metacognitive evaluation, drawing from the general concept of evaluation, involves a learner's capacity to assess what they have learned and determine the most effective ways they learn best.

This skill entails reflecting on how successfully learning objectives have been met, often after completing a unit or receiving feedback. Evaluation typically occurs at the end of a process and guides how subsequent learning steps will be adjusted. The ability to review and judge one's learning progress is likely responsible for the observed positive relationship between metacognitive evaluation and biology performance.

5.6. Combined Influence of Self-Efficacy and Meta-Cognitive Factors on Academic Performance in Biology

The analysis further indicated that the combined presence of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, and metacognitive evaluation was significantly related to academic achievement in biology. Multiple regression analysis revealed that among these factors, metacognitive regulation made a particularly strong contribution to performance, whereas the other variables did not individually contribute significantly in the model.

This suggests important implications for science teaching and learning in secondary schools. In particular, educators should focus on fostering students' metacognitive regulation abilities, as these skills appear to have the most pronounced impact on their academic results.

6. CONCLUSION AND RECOMMENDATIONS

Given that science self-efficacy was found to have a strong positive relationship with biology performance, it can be concluded that students who have greater confidence in their scientific capabilities tend to excel academically. High self-efficacy encourages persistence, goal commitment, and resilience, thereby promoting higher achievement.

It is therefore advised that deliberate measures be taken to strengthen students' self-efficacy. Such measures might include engaging them in hands-on scientific experiments, implementing project-based learning, and providing access to role models and mentors who can inspire and guide them toward academic excellence.

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