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SCIENCE SELF-EFFICACY AND META-VARIABLES AS CORRELATES OF CRITICAL THINKING LEVEL 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' critical thinking in Biology among secondary school students in Kogi East, Nigeria. Guided by 6 research questions, 6 null hypotheses were tested at a 0.05 significance level. The study adopted a correlational design. The population included 9001 Senior Secondary 2 students, with a sample of 382 students selected from five schools using a multistage sampling technique. Data were collected using the researcher-designed Biology Critical Thinking Test (BCTT), Biology Self-Efficacy Scale (BSES), and Biology Meta-Variable Scale (BMVS). These instruments were validated by experts in science education and measurement and evaluation and trial tested. The reliability coefficients of 0.80 (BCTT), 0.89 (BMVS), and 0.82 (BSES) were found. Regression analysis addressed research questions, while ANOVA tested the hypotheses. Results indicated that Science self-efficacy positively correlated with critical thinking ($r = 0.124$, $R^2 = 0.015$). Meta-awareness, meta-regulation, meta-monitoring, and meta-evaluation significantly correlated with critical thinking, with meta-evaluation showing the strongest relationship ($r = 0.840$, $R^2 = 0.706$). The combined influence of science self-efficacy and meta-variables on Biology critical thinking ($r = 0.188$, $R^2 = 0.035$) was also significant. Findings suggest that higher science self-efficacy enhances critical thinking 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 critical thinking through case studies, debates, and scientific investigations, along with inquiry-based learning, can further enhance students' analytical abilities.

Keywords: Science Self-Efficacy, Critical thinking, Biology, Meta Variables, Meta Awareness, Meta-Regulation, Meta-Monitoring, Meta-Evaluation.

Introduction

The place of Biology in the school curriculum cannot be over-stressed. As a subject that focuses on the processes that determine the existence of life, it is fitting and proper for students in secondary schools to understand these processes and how they apply in real-life situations. Green (2022) pointed out that Biology is concerned with living things and their vital processes. Vital processes as used here refer to the stages the cell undergoes and the stages of development in animals (zoology). Biology also encompasses the structure of an organism (morphology) and the function of organisms (physiology) (Green, 2022). As a subject that educates the learner on the presence of life forms, Biology is directly applicable to student's knowledge and as such, there is a need to help learner to understand concepts and their practical implications which could lead to enhancement of critical thinking ability of individuals.

Critical thinking is an invaluable skill in education. The term was first popularised by neo-Dewey. According to Dewey (as cited in Hitchcock, 2011), critical thinking is an active and careful consideration of any belief or knowledge in light of what supports it, and the further conclusions to which it tends. This definition considers the critical thinker as an individual who gathers evidence from his/her experiences before accepting or rejecting a belief or notion. Perez (2019) explained critical thinking simply as an analysis of facts to form a judgment. These definitions of critical thinking establish its relevance in education since learning is a product of good thinking.

In recent times, critical thinking is at the nucleus of every functional learning. Singh (2021) opined that critical thinking enhances creativity and curiosity, promotes assertion and self-reflection, boosts career prospects and nurtures problem-solving and innovation. Again, Shirazi and Heidari (2019) found that critical thinking better improves students learning of STEM (Science, Technology, Engineering and Mathematics). To properly address the poor performance of students in Biology and their inability to think critically, there is a need to investigate other factors that may influence students' critical thinking such as motivation and engagement, emotional intelligence and metacognitive abilities. Matacognitive abilities includes metacognitive regulation in forms of planning, monitoring and evaluation.

Self-efficacy is a psychological term that is highly valid in learning. According to Bandura (2012), self-efficacy refers to an individual's belief in his or her capacity to execute behaviours necessary to produce specific performance attainments (an individual's motivation towards carrying out a particular goal or Task). Self-efficacy entails confidence in the will to control one's motivation, behaviour and social environment; these cognitive self-evaluations influence all manner of human experience, including the goals for which people strive, the amount of energy expended toward goal performance or critical thinking development, and the likelihood of attaining particular levels of behavioural performance. Self-efficacy can be a vital determinant of academic performance and critical thinking. According to Hu et al. (2022), science self-efficacy is responsible for the lack of willingness on the part of students to offer science subjects in school. Ayllon et al. (2019) in their study on teachers' involvement and students' self-efficacy: Keys to achievement in higher education shows that high level of self-efficacy predicts better academic performance than low level of self-efficacy, that is, there is a positive relationship between performance and higher values of student' efforts (self-efficacy; perception that one is learning) in life sciences and medicine among higher education learners. This may be same situation with critical thinking. Equally, it was reported that self-efficacy can influence the choice of tasks and prevalence while carrying the task; that the higher the self-efficacy, the greater the likelihood of relying on self in obtaining solutions and persisting longer to overcome the challenges (Hayat et al., 2020).

In recent times, research has focused on explaining contemporary terms in relation to education. One of these terms is metacognition. Having been coined by Flavell (1979), metacognition is seen as thinking about thinking or our ability to know what we know or what we do not know (Siddiqui & Dubey, 2018; Achor et al, 2022a; Burns et al., 2024). This entails that metacognition explains the ability of the learner to be aware, monitor, control, and regulate his or her cognitive processes. Metacognition is concerned with higher mental processes involved in learning, which range from making learning plans, using appropriate skills and strategies to solve a problem, making estimates of performance to calibrating the extent of learning (Siddiqui & Dubey, 2018). Metacognition pertains to a student's ability to self-critique his or her approach to a task and adapt his or her thinking to improve his or her understanding. The metacognition cycle guides students to improve the way they learn, assess the task, evaluate strengths and weaknesses, plan the approach, apply strategies and reflect (Loveless, 2022). Among the components of metacognition proposed by Flavell in Nazarieh (2016) are: meta-awareness (metacognition knowledge), meta-regulation (metacognitive regulation), metacognitive monitoring and metacognitive evaluation.

Meta-awareness or metacognitive awareness is a component of metacognitive thinking that deals with an individual's realization of his or her cognitive processes. Samuel and Okonkwo (2021) viewed that awareness (knowledge of cognition) focuses on knowing the metacognitive factors that influence our learning and performance, understanding appropriate strategies or ways to improve our learning processes, and knowing which strategies to select to increase our ability to control and manage our mental processes. This implies that meta-awareness is subjective as it is the sole responsibility of an individual to figure out how his or her cognitive process works. For example, a child who understands that the best way he can read and understand concepts in Biology, is by linking them to real-life situations in his or her environment can be said to understand his cognitive processes about Biology. Research findings (Rahman et al, 2010; Ajayi et al, 2020; Özçakmak et al, 2021; Achor et al, 2022b). have shown that students' academic performance is in one way or the other linked to meta-awareness.

Another viable meta-variable that is within the scope of the present study is meta-regulation. Meta-regulation pertains to learners' ability to keep track of their knowledge or learning; it includes their ability to find out what, when, and how to use a particular skill for a given task (Strom et al, 2022). Meta-regulation is vital in science learning as observed by Ucan and Webb (2015); Khosa and Volet (2014), and Greene and Azevedo (2010) who independently stressed that insufficient development of meta-regulation may generate students' knowledge misconceptions in a science discipline and learning difficulties and decrease the students' learning motivation. Bakar and Ismail, (2020) explored the relatedness of meta-regulation to achievement in Mathematics and found that meat-regulation has a moderate effect on achievement in Mathematics. Conversely, Stephanou and Mpiontini (2017) found that metacognitive regulation has profound effect on the academic performance of students across different subject areas. Meta-regulation as a meta-variable is closely related to metacognitive monitoring.

Metacognitive monitoring is one of the principal components of metacognition that explains how the learner keeps tabs on his or her cognitive process. Metacognitive monitoring refers to the monitoring of one's thought processes and one's existing state of knowledge. The ability to monitor one's comprehension during text reading or other learning exercises is fundamental in everyday life, as well as at school (Mirandola et al, 2018). Wagener (2016) who ascertained the relationship between metacognitive monitoring and students' academic performance submitted that contemporary emphasis on self-regulated learning can only come to fruition when teachers properly develop the metacognitive control of students. The finding by Malone and Hurami (2019) that metacognition monitoring helps students perform better reiterates the relevance of the skill in school.

Metacognitive evaluation is concerned with providing a valued judgment about one's cognitive process. It is evident that many variables exist to explain the cause of poor performance; the purpose of metacognitive evaluation is to encourage students to think about such problems by reflecting upon themselves through self-evaluation (Choi, 2006). Metacognitive reflection, however, takes thinking processes to the next level because it is concerned not with assessment, but with self-improvement (Watanabe-Crockett, 2018). Metacognitive evaluation is usually a personal endeavour by which the individual access the learning material and figures out how best his or her cognitive or thinking process works. In science, metacognitive evaluation comes into play when the students self-evaluate his or her metacognitive process to figure out how he or she can better learn and understand concepts in science. For example, a student who has been learning the biological names of plants by rote memorization and change this method of memorization and learning after an evaluation of the effectiveness of the method in helping him or her remember the biological names of plants for a longer period

While existing studies have explored self-efficacy and meta-variables as individual predictors of students' critical thinking in Biology, there is limited research on their combined impact on students' critical thinking in Biology in Nigeria and Kogi State in particular. This study seeks to fill this gap by examining the correlations between science self-efficacy, meta-variables, and Biology critical thinking. Understanding these relationships can provide valuable insights for educators and policymakers seeking to improve students' outcomes in Biology and foster critical thinking skills.

Statement of the Problem

The critical thinking ability of students in science is always of concern to parents, teachers and examination boards in Nigeria because it is strongly linked to their academic performance and success in future endeavour. With the overwhelming importance of Biology, the critical thinking of students in this subject has not been impressive in recent years and this is corroborated by a consistent pattern of poor outcomes in both internal and external assessments, including the West African Senior School Certificate Examination (WASSCE). The West African Examinations Council (WAEC) Chief Examiners have reported this trend for instance, the performance of Biology students over the years has been poor (WAEC, 2013-2022). 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 and meta-variables?

Contemporary research has related students' critical thinking in the classroom to self-efficacy and other psychological constructs of metacognition and its variables which range from meta-awareness, metacognitive regulation, metacognitive monitoring and metacognitive evaluation. An understanding of these concepts and ascertaining their relatedness or otherwise to critical thinking of students in Biology could better address the issue of poor level of critical thinking in Biology. It is in line with this premise that the researchers set out to address the question: how do science self-efficacy and meta-variables correlate with Biology critical thinking among secondary school students in Kogi East Education Zone, Nigeria?

Objectives of the Study

The objectives of the study were to:

1. Find out the relationship between science self-efficacy and critical thinking of students in Biology
2. Verify the relationship between science meta-awareness and critical thinking of students in Biology.
3. Ascertain the relationship between science metacognitive regulation and critical thinking of students in Biology.
4. Ascertain the relationship between science metacognitive monitoring and critical thinking of students in Biology
5. Find out the relationship between science metacognitive evaluation and critical thinking of students in Biology.
6. Determine the relationship between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology

Research Questions

The following research questions guided the study:

1. What is the relationship between self-efficacy and critical thinking of students in Biology?
2. What is the relationship between science meta-awareness and critical thinking of students in Biology?
3. What is the relationship between science metacognitive regulation and critical thinking of students in Biology?
4. What is the relationship between science metacognitive monitoring and critical thinking of students in Biology?
5. What is the relationship between science metacognitive evaluation and critical thinking of students in Biology?
6. What is the relationship between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology?

Hypotheses

The following hypotheses formulated guided the study at 0.05 level of significance:

1. There is no significant relationship between science self-efficacy and critical thinking of students in Biology
2. There is no significant relationship between science meta-awareness and critical thinking of students in Biology
3. There is no significant relationship between science metacognitive regulation and critical thinking of students in Biology.
4. There is no significant relationship between science and critical thinking of students in Biology
5. There is no significant relationship between science metacognitive evaluation and science critical thinking of students in Biology.
6. There is no significant relationship between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology.

Method

Methods in this study includes research design, population, sample and sampling, instrument validation and method of data collection.

Research Design

This study adopted the correlational research design. The design sought to establish what relationship that existed between two or more variables (Emaikwu, 2015). According to Emaikwu, correlation studies usually indicate the direction and magnitude of the relationship between the variables. The researcher does not manipulate or control any of the variables under study. The design also employed a special group of the statistics known as correlation co-efficient for data analysis.

The design was chosen due to the nature of the present study and the processes involved in the collection of data. The design was considered most appropriate for the study because the study seeks to provide answers to the research question as well as test the hypotheses about the possible correlation among indices of self-efficacy, metavariables, academic performance and critical thinking.

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 Biology students because any remediation at this level could help this category of students in external examinations especially that conducted by the West Africa Examination Council and the National Examination Council.

The sample size for this study was 382 SS2 students selected from the population of 9001 using Yamane's (1967) formula for determining sample size**.** The researcher used multi-stage sampling technique to properly distribute the sample size. It is multi-stage because different sampling techniques were employed at the stages of the sampling. Firstly, the researcher employed purposive sampling technique to sample three local governments area out of the nine local government areas and five schools from the area.

At the second stage, the researcher adopted 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 simple random sampling technique to select individual participants in the study. Hat and draw procedure was particularly used. The researcher proceeded by writing "YES" and "NO" on pieces of paper. Students who pick YES was selected for the study while those who picked NO were not selected. The researcher continues this till he arrived at 382.

Instrument, Validation and Reliability

The researcher used a total of three instruments for the collection of data. The instruments were the researcher designed Biology Critical Thinking Test (BCTT), Biology Self-Efficacy Scale (BSES) and Biology Meta-Variables Scale (BMVS).

The Biology Critical Thinking Test (BCTT) is also researcher designed essay test. It assesses students' level of critical thinking and has a total of 20 items. Designed to measure students' ability to apply logical reasoning, analyse information, interpret data, and solve problems in Biology. The tests include real-life biological scenarios and data analysis tasks that require critical thinking beyond rote memorization. Correct answer for each question attracts 5 marks and total obtainable mark is 100 as shown in the marking guide.

Biology Meta-Variable Scale (BMVS) was also developed by the researcher, but unlike the BCTT, the BMVS is a questionnaire. The instrument has four clusters of meta-awareness, metacognitive monitoring, metacognitive regulation and metacognitive evaluation. Each of these clusters has a total of ten items. The response pattern is in line with adapted Likert scale of 1=Strongly Disagree, 2= Disagree, 3=Agree and 4 = Strongly Agree for dichotomously skewed items.

The Biology Self-efficacy scale (BSES) was adapted from Scherer's et al, General Self Efficacy Scale (1982), which is made up of 23 items rated on a 5-point Likert scale of 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree and 5= Strongly Agree. The current one is modified to suit the goals of this study. The Biology Self-Efficacy Scale has a total of 30 items. The researcher changed the response pattern to a 4-point Likert-type scale of 1=Strongly Disagree, 2= Disagree, 3=Agree and 4 = Strongly Agree in order to provide a wide range of options for respondents. The scoring was reversed for negative statements. The total score ranges between 30 and 120 with a higher score indicating higher self-efficacy.

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 faculty of education, Benue State University, Makurdi. The experts reviewed and validated the research instruments to ensure it meets the necessary standards for reliability, validity, and relevance to the study's objectives. They also carried out face and content validation of the BCCT, BMVS and BSES while Table of specification was used to validate the BCTT.

The validators commented and suggested that the number of items in the instruments particularly the Biology Critical Thinking Test (BCTT) and Biology Self-Efficacy Scale (BSES|) should be reduced and that the items on BCTT should reflect higher order level of cognitive domains. Other observations were on semantics particularly on Biology Meta-Variable Scale (BMVS) and Biology Self-Efficacy Scale (BSES). The researcher ensured that the number of items are in tandem with the objectives of the study as well considered the higher order level of cognitive domain for critical thinking test. Items 5 and 28 of BSES were discarded for meeting the criteria for selection from the factor analysis.

The instruments were 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 analyse the reliability coefficient of the instrument. Kuder Richardson was used to determine the reliability of Biology Critical Thinking Test (BCTT) since the items in the instruments are dichotomously scored. Cronbach Alpha was used to establish the reliability of Biology Meta-Variable Scale (BMVS) and the Biology Self-Efficacy Scale because it is suitable for scores using scales and also as its focus is mainly on internal consistency.

The reliability coefficient of the BCTT yielded 0.80. A cluster-by-cluster analysis was conducted to determine the reliability of Biology Meta-Variable scale (BMVS). Clusters 1 to 4 yielded 0.6, 0.57, 0.79 and 0.73 respectively. The full-length reliability of the instrument is 0.89. The reliability of Biology Self-Efficacy Scale (BSES) yielded a coefficient of 0.82.

Item analysis using factor analysis was carried out on the Biology Self-Efficacy Scale (BSES) and Meta Variable Scale (BMVS) to establish their construct validity. Construct validation was done for Biology Self-Efficacy Scale (BSES) and Biology Meta-Variable Scale (BMVS) 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 the choice of construct validation is because students' power to think consists of several almost uncorrelated functioning parts known as factors which could be identified through a technique known as factor analysis.

The item selection was done using the rotated component matrix. The items with factor loading of 0.35 and above on any of the factors were identified and selected to be part of the final form of the instruments and those that fail to load up to 0.35 were discarded. Therefore, items 5 and 28 which failed to load up to 0.35 were discarded from the BSES.

Collection and Analysis

Five teachers who teach Biology in the sampled schools served as research assistants. The critical test instrument was administered to the students after which the questionnaires were subsequently administered. The researcher briefed the assistants on how to administer the instruments. First, Biology Critical Thinking Test (BCTT) was administered which lasted for one hour, this was followed by Biology Self-Efficacy Scale (BSES) which lasted for 30 minutes. After break period, Biology Meta-Variable Scale (BMVS) which lasted for 30 minutes was administered. The total time covered for all tests put together is 2 hours. The data collection process lasted for a period of two days.

The research questions were answered using regression analysis. This measured 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.

ANOVA of regression was used to test the hypotheses at 0.05 level of significance. Regression Analysis went a step further by assessing the predictive power of science self-efficacy and meta-variables on student critical thinking and performance. By testing the hypotheses, regression analysis revealed how well these independent variables (self-efficacy and meta-variables) explain the variance in the dependent variable (critical thinking). 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.

Results

The data presented are analysed using regression analysis to answer research questions and test the hypotheses at a 0.05 level of significance. The decision rule was that null hypotheses were rejected if the P-value was less than 0.05 and not rejected if otherwise.

Research Question One: What is the relationship between self-efficacy and critical thinking of students in Biology?

Table 1: Regression Analysis of Relationship between Self-efficacy and Critical Thinking of Students in Biology

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.124[a]	.015	.013	7.54658

Table 1 shows the regression of the relationship between science self-efficacy and critical thinking of students in Biology. The table reveals the linear regression model of science self-efficacy and critical thinking of students in Biology. The analysis shows that the correlation between science self-efficacy and critical thinking of students in Biology is 0.124 with a coefficient of determination of 0.015. This implies that 1.5 percent of the critical thinking of students in Biology is attributed to their science self-efficacy. Therefore, the relationship between science self-efficacy and critical thinking of students in Biology is 0.124.

Research Question Two: What is the relationship between science meta-awareness and critical thinking of students in Biology?

Table 2: Regression Analysis of Relationship between Science Meta-awareness and Critical Thinking of Students in Biology

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.401[a]	.161	.160	7.56614

Table 2 shows the regression of the relationship between science meta-awareness and critical thinking of students in Biology. The table reveals the linear regression model of science meta-awareness and critical thinking of students in Biology. The analysis shows that the correlation between science meta-awareness and critical thinking of students in Biology is 0.401 with a coefficient of determination of 0.161. This implies that 16.1 percent of critical thinking of students in Biology is accounted for by their science meta-awareness. Therefore, the relationship between science meta-awareness and critical thinking of students in Biology is 0.401.

Research Question Three: What is the relationship between science metacognitive regulation and critical thinking of students in Biology?

Table 3: Regression Analysis of Relationship between Science Metacognitive Regulation and Critical Thinking of Students in Biology

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.690[a]	.476	.470	7.57422

Table 3 shows the regression of the relationship between science metacognitive regulation and critical thinking of students in Biology. The table reveals the linear regression model of science metacognitive regulation and critical thinking of students in Biology. The analysis shows that the correlation between science metacognitive regulation and critical thinking of students in Biology is 0.690 with a coefficient of determination of 0.476. This implies that 47.6 percent of critical thinking of students in Biology is accounted for by their science metacognitive regulation. Therefore, the relationship between science metacognitive regulation and critical thinking of students in Biology is 0.690.

Research Question Four: What is the relationship between science metacognitive monitoring and critical thinking of students in Biology?

Table 4: Regression Analysis of Relationship between Science Metacognitive Monitoring and Critical Thinking of Students in Biology

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.626[a]	.392	.390	7.60247

Table 4 shows the regression of the relationship between science metacognitive monitoring and critical thinking of students in Biology. The table reveals the linear regression model of science metacognitive monitoring and critical thinking of students in Biology. The analysis shows that the correlation between science metacognitive monitoring and critical thinking of students in Biology is 0.626 with a coefficient of determination of 0.392. This implies that 39.2 percent of critical thinking of students in Biology is accounted for by their science metacognitive monitoring. Therefore, the relationship between science metacognitive monitoring and critical thinking of students in Biology is 0.626.

Research Question Five: What is the relationship between science metacognitive evaluation and critical thinking of students in Biology?

Table 5: Regression Analysis of Relationship between Science Metacognitive Evaluation and Critical Thinking of Students in Biology

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.840[a]	.706	.700	7.59906

Table 5 shows the regression of the relationship between science metacognitive evaluation and critical thinking of students in Biology. The table reveals the linear regression model of science metacognitive evaluation and critical thinking of students in Biology. The analysis shows that the correlation between science metacognitive evaluation and critical thinking of students in Biology is 0.840 with a coefficient of determination of 0.706. This implies that 70.6 percent of critical thinking of students in Biology is accounted for by their science metacognitive evaluation. Therefore, the relationship between science metacognitive evaluation and critical thinking of students in Biology is 0.840.

Research Question Six: What is the relationship between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology?

Table 6: Regression Analysis of Relationship between the Combination of Science Self-efficacy, Meta-awareness, Metacognitive Regulation, Metacognitive Monitoring, Metacognitive Evaluation and Critical Thinking of Students in Biology

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
5	.188[e]	.035	.022	7.51058

Table 6 shows the regression of the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology. The table reveals the linear regression model of a combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology. The analysis reveals that the correlation between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology is 0.188 with a coefficient of determination of 0.035. This implies that 3.5 percent of critical thinking of students in Biology is accounted for by the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation. Therefore, the relationship between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology is 0.188.

Hypotheses One: There is no significant relationship between science self-efficacy and critical thinking of students in Biology.

Table 7: ANOVA of the Relationship between Science Self-efficacy and Critical Thinking of Students in Biology

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	322.013	1	322.013	5.654	.018
	Residual	20673.181	363	56.951		
	Total	20995.195	364			

Table 7 reveals that F (1,364) = 5.654; p = 0.018 < 0.05. Thus, the null hypothesis is rejected. This implies that there is significant relationship between science self-efficacy and critical thinking of students in Biology. Thus, based on evidence from data analysis there is significant association between science self-efficacy and critical thinking of students in Biology.

Hypotheses Two: There is no significant relationship between science meta-awareness and critical thinking of students in Biology.

Table 8: ANOVA of Relationship between Science Meta-awareness and Critical Thinking of Students in Biology

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	214.709	1	214.709	3.751	.050
	Residual	20780.486	363	57.247		
	Total	20995.195	364			

Table 8 reveals that F (1,364) = 3.751; p = 0.050 < 0.05. Thus, the null hypothesis is rejected. This implies that there is significant relationship between science meta-awareness and critical thinking of students in Biology. Thus, based on evidence from data analysis, there is significant relationship between science meta-awareness and critical thinking of students in Biology.

Hypotheses Three: There is no significant relationship between science metacognitive regulation and critical thinking of students in Biology.

Table 9: ANOVA of Relationship between Science Metacognitive Regulation and Critical Thinking of Students in Biology

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	170.339	1	170.339	2.969	.016
	Residual	20824.855	363	57.369		
	Total	20995.195	364			

Table 9 reveals that F (1,364) = 2.969; p = 0.016 < 0.05. Thus, the null hypothesis is rejected. This implies that there is significant relationship between science metacognitive regulation and critical thinking of students in Biology. Thus, based on evidence from data analysis, there is significant relationship between science metacognitive regulation and critical thinking of students in Biology.

Hypotheses Four: There is no significant relationship between science metacognitive monitoring and critical thinking of students in Biology.

Tab1e 10: ANOVA of Relationship between Science Metacognitive Monitoring and Critical Thinking of Students in Biology

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	14.668	1	14.668	.254	.015
	Residual	20980.527	363	57.798		
	Total	20995.195	364			

Table 10 reveals that F (1,364) = 0.254; p = 0.015 < 0.05. Thus, the null hypothesis is rejected. This means that there is significant relationship between science metacognitive monitoring and critical thinking of students in Biology. Thus, based on evidence from data analysis, there is significant relationship between science metacognitive monitoring and critical thinking of students in Biology.

Hypotheses Five: There is no significant relationship between science metacognitive evaluation and science critical thinking of students in Biology.

Table 11: Regression Analysis of Relationship between Science Metacognitive Evaluation and Science Critical Thinking of Students in Biology

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	33.510	1	33.510	.580	.047
	Residual	20961.684	363	57.746		
	Total	20995.195	364			

Table 11 reveals that F (1,364) = 0.580; p = 0.047 < 0.05. Thus, the null hypothesis is rejected. This implies that there is a significant relationship between science metacognitive evaluation and science critical thinking of students in Biology. Thus, based on evidence from data analysis, there is a significant relationship between science metacognitive evaluation and science critical thinking of students in Biology.

Hypotheses Six: There is no significant relationship between the combination of science self-efficacy, metacognitive awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology.

Table 12: Stepwise Multiple Regression Analysis of Relationship between the Combination of Meta-variables and Critical Thinking of Students in Biology

Model		Sum of Squares	Df	Mean Square	F	Sig.
5	Regression	744.424	5	148.885	2.639	.023
	Residual	20250.771	359	56.409		
	Total	20995.195	364			

Table 12 reveals that F (5, 364) = 2.639; p = 0.023 < 0.05. Thus, the null 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 critical thinking of students in Biology. Thus, based on evidence from data analysis, there is a significant relationship between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology.

Table 13: Contributions of Meta-variables in the Overall Relationship with Critical Thinking of Students in Biology

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
5	(Constant)	23.060	6.071		3.799	.000
	Science self-efficacy	2.983	1.301	.119	2.292	.022
	Science meta-awareness	3.523	4.370	.131	.806	.421
	Science metacognitive regulation	1.285	4.331	.048	-.297	.767
	Science metacognitive monitoring	3.583	2.110	.158	1.699	.090
	Science metacognitive evaluation	-4.470	2.154	.190	-2.075	.039

a. Dependent Variable: Critical thinking of students in Biology

Table 13 shows standard multiple regression analysis of the meta-variables and Critical thinking of students in Biology. The table shows that the Science self-efficacy has a predictive power of 0.119, making 11.9 percent contribution to the critical thinking of students in Biology at $P = 0.022 < 0.05$. This means that Science self-efficacy significantly contributed to students' critical thinking in Biology. Science meta-awareness has a predictive power of 0.131, making 13.1 percent contribution to critical thinking of students in Biology at $P = 0.421 > 0.05$. This means that Science meta-awareness does not make a significant contribution to the critical thinking of students in Biology. Science metacognitive regulation has a predictive power of 0.048, making 4.8 percent contribution to the critical thinking of students in Biology at $P = 0.767 > 0.05$. This means that Science metacognitive regulation does not make a significant contribution to the critical thinking of students in Biology. Science metacognitive monitoring has a predictive power of 0.158, making 15.8 percent contribution to the critical thinking of students in Biology at $P = 0.090 > 0.05$. This means that the Science metacognitive monitoring does not make a significant contribution to the critical thinking of students in Biology. Science metacognitive evaluation has a predictive power of 0.190, making 19.0 percent contribution to the critical thinking of students in Biology at $P = 0.039 < 0.05$. This means that the Science metacognitive evaluation made a significant contribution to the critical thinking of students in Biology. The order of contributions of the meta-variables to the overall significance of the regression with performance of students in Biology is: Science metacognitive regulation (4.8%) to science self-efficacy (11.9%) to science meta-awareness (13.1%) to science metacognitive monitoring (15.8%) to science metacognitive evaluation (19.0%).

Discussion of Findings

The study made a number of findings that are discussed in this section. Finding revealed that there was a significant relationship between science self-efficacy and critical thinking of students in Biology. This means that science self-efficacy is a significant determinant of critical thinking of students in Biology. The finding agrees with Dehghani et al (2011) that a significantly positive relation exists between students' self-efficacy and critical thinking. The finding agrees with Tan et al (2023) that there is a significant positive relationship between science self-efficacy and the socioeconomic statuses of parents. The finding agrees with Solikah et al. (2023) that self-efficacy was significantly related to junior high school students' critical thinking skill in motions and forces materials and that each dimension of self-efficacy positively affected the students' critical thinking skill. Science self-efficacy builds on the fact that students with a higher sense of science self-efficacy have more confidence in their abilities, a greater willingness to complete science tasks, and a stronger perseverance in completing difficult science tasks. The reason behind the domain of self-efficacy is that confidence is the pivot to success; believing one's strengths supports one even under undesirable situations and conditions, makes students critical thinkers. As such, being successful requires consistent performance and this heavily depends upon how an individual think critically to deal with the situations or changes coming forth in his life. This may be responsible for the significant relationship found between science self-efficacy and critical thinking of students in Biology.

Another finding in this study revealed that there was a significant relationship between science meta-awareness and critical thinking of students in Biology. This denotes that science meta-awareness is a significant determinant of critical thinking of students in Biology. The finding agrees with Khairinaa1et al (2023) that metacognitive awareness is a mediator of the relationship between trait mindfulness and critical thinking. Meta-awareness has been found to improve the level of critical thinking of an individual. Critical thinking is concerned with higher-order thinking skills that enable individuals to successfully participate in a society. Critical thinking skills allow individuals to become independent thinkers, capable of analysing and solving problems. Among an extensive inventory of critical thinking skills, we have analysis, interpretation, inference, explanation, synthesis, evaluation, reasoning, self-regulation, decision-making and problem solving. The skills of critical thinking are possible with a significant mastery of meta-awareness on the part of the student. This may be responsible for the significant relationship found between science meta-awareness and critical thinking of students in Biology.

This study has revealed that there was a significant relationship between science metacognitive regulation and critical thinking of students in Biology. This denotes that science metacognitive regulation is a significant determinant of critical thinking of students in Biology. Metacognitive regulation is needed in learning to improve the activeness of a learner. A self-regulated learner can think critically to understand what is involved in a task, identify personal strengths and weaknesses related to the task, create a plan for completing the task, monitor how well the plan is working, and evaluate and adjust the plan as needed. These processes are important in metacognitive regulation as it helps the individual to control what he learns, the pace he learns and the manner the information is arranged for proper comprehension and recall. This may be responsible for the significant relationship found between science metacognitive regulation and critical thinking of students in Biology.

Further finding from the study revealed that there was a significant relationship between science metacognitive monitoring and critical thinking of students in Biology. This means that science metacognitive monitoring is a significant determinant of critical thinking of students in Biology. Metacognition monitoring makes it possible for the learner to discover his inadequacies in learning. The students are found to be active in monitoring their learning processes, and taking note of concepts that they can easily understand and then the ones that are giving them a hard time, as they have impressive metacognitive monitoring skills. This may be responsible for the significant relationship found between science metacognitive monitoring and critical thinking of students in Biology. Additional finding revealed that there was a significant relationship between science metacognitive evaluation and science critical thinking of students in Biology. This implies that science metacognitive evaluation is a significant determinant of critical thinking of students in Biology. The finding agrees with Naimnule and Corebima (2018) that there exists a strong positive correlation between metacognitive evaluation skill and students' critical thinking in science process skills. The finding agrees with Rivas et al (2022) that metacognition improves due to critical intervention, as well as how critical thinking also improves with metacognitive intervention and Critical thinking skills intervention. The finding agrees with Khairinaa1et al (2023) that there is a relationship between critical thinking skills and knowledge learning outcomes in science learning. Metacognitive evaluation entails the process of judging the quality of a work product against a standard. Metacognitive evaluation is also the process of assessing the level of success or otherwise of learning. It applies to both the teacher and the student. The purpose of metacognitive evaluation is to encourage students to think about such problems by reflecting upon themselves through self-evaluation. This may be responsible for the significant relationship found between science metacognitive evaluation and science critical thinking of students in Biology.

Further findings revealed that there was a significant relationship between the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, metacognitive evaluation and critical thinking of students in Biology. This signifies that the combination of science self-efficacy, meta-awareness, metacognitive regulation, metacognitive monitoring, and metacognitive evaluation is a significant determinant of critical thinking of students in Biology. The standard multiple regression of the meta-variables and Academic performance of students in Biology revealed that Science self-efficacy and Science meta-metacognitive evaluation made significant contribution to Critical thinking of students in Biology. However, Science meta-awareness, Science meta-cognitive regulation and Science meta-metacognitive monitoring do not make significant contribution to Critical thinking of students in Biology.

Conclusion and Recommendations

This study shows that science self-efficacy and metavariables have significant relationship with critical thinking in Biology. Based on the study's findings that science self-efficacy and meta-variables show a positive and significant relationship with biology students' critical thinking in secondary schools, it could be concluded that science self-efficacy enhances critical thinking because, a strong sense of confidence in scientific abilities is linked to improved critical thinking skills, meaning students with higher self-efficacy are more likely to analyse and evaluate biological concepts effectively. Meta-variables play a crucial role as factors such as meta-awareness, metacognitive regulation, metacognitive monitoring and metacognitive evaluation (meta-variables) significantly impact students' Biology ability to think critically.

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

1. There should be concise efforts towards enhancing science self-efficacy such as could lead to confidence building activities like hands-on experiments, project based, exposing students to role models and mentors.
2. Strengthening metacognitive skills through integration of metacognitive training in the curriculum which can help students develop self-awareness as well-set goals for themselves and monitor selves

3. Improve Biology instruction through adoption of teaching methods that promote active engagement like problem solving tasks, group discussions and use of realia which enhance critical thinking.
4. Encouraging development of critical thinking through exercises, such as case studies, debates, and scientific investigations, into biology lessons. Use open-ended questions that challenge students to analyse, evaluate, and synthesize information. Promote inquiry-based learning to encourage curiosity and independent problem-solving.

References

Achor, S. Z., Zaria, L. I. & Achor, E. E. (2022a). Impact of Metacognitive Awareness on Basic Eight Students' Performance in Social Studies. *Research in Social Sciences,* 5(1), 10-21. *DOI:10.53935/26415305.v5i1.212.*

Achor, E. E., Ellah, B. O. & Omaga, J. O. (2022b). Misconceptions and difficult concepts as determinant of students' academic engagement and retention in physics. *Journal VARIDIKA*, 34(1), 42-52.DOI: 10.23917/varidika.v1i1.17660.

Ajayi, V. O., Achor, E. E., & Otor, E. E. (2020). Will collaborative think-and-do activity enhance students' academic performance in chemistry? A field report. *Benue State University Journal of Education, 20*(1), 1–10.

Burns, E., Khadka, J., & Kanninen, S. (2024). Metacognition: An intriguing concept for teachers in Nepal. *ARENA PRO*. Retrieved October 20, 2024, from https://arena.jamk. fi/en/arena-pro/ metacognition-intriguing-concept-for-teachers-in-nepal

Ayllon, S., Alshina, A., & Colomer, J. (2019). Teachers' involvement and students' self-efficacy: Keys to achievement in higher education. *PLoS ONE, 14*(5). https://doi.org/10. 1371/journal.pone.0216865

Bandura, A. (2012). On the functional properties of perceived self-efficacy revisited. *Journal of Management, 38*(1), 9–44. https://doi.org/10.1177/ 0149206311410606

Choi, J. Y. (2006). Metacognitive evaluation method in consecutive interpretation for novice learners. *Meta: Journal des Traducers/Translators' Journal,* 51(2), p. 273–283. Retrieved March 7, 2023, from https://www. erudit.org/en/ journals/meta/1900-v1-n1-meta1279/013256ar/

Dehghani, M., Jafari, H. S., Pakmehr, H. & Malekzadeh, A (2011). Relationship between students' critical thinking and self-efficacy beliefs in Ferowsi University of Mashhad, Iran. *Procedia-Social and Behavioural Sciences.* 15. 2952-2955

Emaikwu. S. O. (2015). *Fundamentals of research methods and statistics*. Selfers Academic Press Limited.

Flavell, J. H. ((1979) Metacognition and cognitive monitoring: a new area of cognitive developmental inquiry. *American Psychologist*. 34, 906-911

Green, E. R. (2022). Biology. Retrieved on March 3rd from https://www. britannica.com/science/biology

Greene, J. A., & Azevedo, R. (2010). The measurement of learners' self-regulated cognitive and metacognitive processes while using computer-based learning environments. *Educ. Psychol. 45, 203–209.*

Hayat, A. A., Shateri, K., Amini, M. & Shokrpour, N (2020). Relationship between academic self-efficacy, learning related emotions, and metacognitive learning-strategies with academic performance in medical students: A structural equation model. *BMC Med Educ., 20*(1):76.

Hitchcock, D. (2011). Critical thinking as an educational ideal. Retrieved on March 10th, 2023 from https://www.researchgate .net/publication /275462988.

Hu, X., Jiang, Y., & Hialin, B. (2022). Measuring science self-efficacy with a focus on the perceived competence dimension: using mixed methods to develop an instrument and explore changes in cross-sectional and in high school. *Journal of Humanities, Arts, Medicine and Sciences, 2*(2), 61-64

Khairinaa1, R., Wahyuningsih, D. & Khasanah, A.N. (2023). Relationship between critical thinking skills and metacognition awareness with learning outcomes in science learning. *Journal of Research in Science Education*. 9(5) 1-7

Kogi State Ministry of Education (2023). *School statistic office, Lokoja*. Kogi State Govt.

Malone, N. & Hurami, A. (2019). *Effects of metacognitive monitoring during problem solving on academic achievement metacognition, studying, and self-regulated learning session.* Retrieved on March 10th, 2023 from https://www.researchgate.net/publication /333676961.

Mirandola, C., Ciriello, A., Gigli, M. & Cornoldi, C. (2018). Metacognitive monitoring of text comprehension: An investigation on postdictive judgments in typically developing children and children with reading comprehension difficulties. *Frontiers in Psychology, 9*. https://doi.org/10.3389 /fpsyg

Naimnule, L & Corebima, A. D. (2018). The correlation between metacognitive skills and critical thinking skills towards student's process skills in Biology learning. *Journal of Pedagogical Research, 2*(2) 122-134

Özçakmak, H., Korkmaz, K.C., Koroglu, M. Bolat, Y. (2021). The effect of metacognitive awareness on academic. *African Educational Research Journal, 9*(2), 434-448.

Perez, N. (2019). The concept of critical thinking. Retrieved on March 10th, 2023 from https://doi.org/10.1373/journal. 0348257

Rivas, S. V., Saiz, C. & Ossa, C. (2022). Metacognitive strategies and development of critical thinking in higher education. *Frontiers in Psychology, 13,1-13.* 13913219. Doi: 10.3389/fpsyg.2022.913219

Rahman, T. (2010). A multilingual language-in-education policy for indigenous minorities in Bangladesh: Challenges and possibilities. *Current Issues in Language Planning, 11*(4):341-359. DOI: 10.1080/14664208.2010.537816

Samuel, N.N.C., Okonkwo, I. G. (2021). Relationship between metacognition, locus of control, and academic achievement in secondary school Chemistry students in Anambra State, Nigeria. *Education Research International,* 1-7. DOI: 10.1155 /2021/6698808

Sherer, M., Maddux, J. E., Mercandante, B., Prentice-Dunn, S., Jacobs, B., & Rogers, R. W. (1982). The Self-Efficacy Scale: Construction and Validation. *Psychological Reports, 51*(2), 663-671. https://doi.org/10.2466 / pr0.1982.51.2.663

Siddiqui, S., Dubey, R. & (2018). Metacognition in the context of education: an overview. *Journal of*

Education in Developing Areas, 28, (2), 127-137. http:// euroasiapub.org

Singh, A. (2021). Critical analysis and writing the critique. *Journal of Education*. SSRN Electronic Journal. DOI: 10.2139/ssrn.3838393.

Solikah, E., Utami, B., Sukamini & Nuhrahem, S. (2023). *The relationship between students' self-efficacy and critical thinking skill in motions and forces materials.* Retrieved 20th October, 2024 from https://pubs.aip.org/aip/acp/article-abstract/2540/1/090008/2873833/The-relationship-between-students-self-efficacy?redirectedFrom=fulltext.

Stephanou, G. & Mpiontini, M. H. (2017). *Metacognitive knowledge and metacognitive regulation in self-regulatory learning style, and its effects on performance expectation and subsequent performance across diverse school subjects*. Retrieved on 10th March, 2023 from https://www.scirp.org/journal/paperinformation.aspx?paperid=79690

Strom, P. S., Strom, D. R. & Wang, C. (2022). Peer and Self-Assessment of teamwork skills in high school: Using a multi-rater evaluation method of cooperative learning groups. *International Journal of Educational Reform 33*(1). https://doi.org/10.1177/10567879221082969

Tan, C.Y, Lin, G., Hong, X & Song, Q (2023). *Socioeconomic status and students' science self-efficacy.* Retrieved 20th October, 2024 from https://doi.org/ 10.1002/berj.3869

Wagener, B (2016). Metacognitive monitoring and academic performance in college. *College Teaching*, *64*(2), DOI: 10.1080/ 87567555.2015.1116056

Watanabe-Cockett, L. (2018). *The Best Self-assessment uestions for encouraging a growth mind-set using metacognitive strategies in Education.* https://www.erudit.org/en/journals/meta/1900-v1-n1-meta1279/013256ar/

West African Examinations Council. (2013-2023). WAEC result analysis. WAEC Press

Yamane, T. (1969). *Statistics: An introductory analysis.* Harper and Row.