

Effects of Self-Regulated Learning Intervention on ... Sada, U., Et. al. (2026)

Effects of Self-Regulated Learning Intervention on Motivation and Academic Performance in Cellular Respiration among Secondary School Students in Katsina State, Nigeria

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Abstract

This study investigated the effect of a Self-Regulated Learning Intervention (SRLI) on motivation and academic performance in Biology among secondary school students in Katsina State, Nigeria. Four research questions and four corresponding null hypotheses were formulated to guide the study. A quasi-experimental, pretest–post-test control group design was adopted to determine the impact of the intervention on students' motivation and academic performance in cellular respiration. From a population of 5,378 SSII students in Dutsin-Ma Education Zone, Katsina State, a multi-stage sample of 85 students was drawn and categorised into experimental ($n = 48$) and control ($n = 37$) groups. Data were collected using the Motivational Strategies for Learning Questionnaire (MSLQ) and a Cellular Respiration Performance Test (CRPT), which were validated by three experts and pilot tested, yielding reliability coefficients of 0.859 and 0.816, respectively. Data were analysed using descriptive statistics and Analysis of Covariance (ANCOVA). Results showed that the SRLI group had significantly higher post-test scores in motivation ($MD = 11.84$) and academic performance ($MD = 3.03$) than the control group. ANCOVA indicated a significant main effect of the intervention on motivation, $F(1, 80) = 39.72, p < .05$, and academic performance, $F(1, 80) = 25.67, p < .05$. No significant gender differences were found for motivation, $F(1, 80) = 1.30, p > .05$, or academic performance, $F(1, 80) = 0.106, p > .05$, indicating that the intervention was equally effective for male and female students. The study concludes that SRLI is a highly effective, gender-inclusive strategy for teaching complex biological concepts and recommends its systematic integration into classroom practice.

Keywords: Self-Regulated Learning Intervention (SRLI), Motivation, Academic Performance.

Introduction

The evolving landscape of 21st-century education has triggered a major shift from traditional, teacher-centred models toward approaches that position learners as active constructors of their own knowledge. International policy frameworks and Nigeria's National Policy on Education emphasise the need to equip learners beyond subject-specific areas but include enduring competencies like critical thinking, metacognition, problem solving, and self-directed learning (Federal Republic of Nigeria, 2013; Organisation for Economic Co-operation and Development [OECD], 2018). These competencies are particularly salient in science education, where Biology underpins national responses to public health challenges, agricultural productivity, and environmental sustainability. Despite the centrality of Biology to national development, persistent concerns remain about students' learning outcomes in the subject across Nigeria and especially in northern states such as Katsina. Cellular respiration and genetics are consistently cited as the most difficult concepts in the Chief Examiners' assessment reports to the West African Examinations Council (WAEC), which show deficiencies in students' conceptual understanding, problem-solving abilities, and capacity to apply knowledge to new circumstances (WAEC, 2022). The 2022 West African Senior School Certificate Examination (WASSCE) biology pass rate in Katsina State was roughly 48%, which is lower than the national average and indicates persistent challenges in grasping basic biological concepts (Katsina State Ministry of Basic and Secondary Education [KSMBSE], 2023). These patterns raise concern not only for individual learners' progression into Science, Technology, Engineering, and Mathematics (STEM) pathways but also for the state's human capital development. In response to these challenges, scholars have increasingly turned to SRL being a promising framework aimed at understanding, improving students' learning processes and outcomes. To be able to achieve desired learning outcomes, SRL is often described as a proactive, cyclical process in which students create objectives, implement strategies, track their progress, and control their motivation, behaviour, and thought processes



Effects of Self-Regulated Learning Intervention on ... Sada, U., Et. al. (2026)

(Zimmerman, 2002; Zimmerman, 2020). Unlike traditional views that frame learning as something done to students, SRL conceptualises learners as agents who plan and manage their own learning, drawing on metacognitive, motivational, and behavioural strategies (Panadero, 2017). The academic performance of Nigerian secondary school pupils in biology, notably in Katsina State, remains a major problem. Biology is an important fundamental scientific topic for developing human capital in fields such as public health, agriculture, and environmental management. However, studies from the West African Examinations Council (WAEC) repeatedly identify weak comprehension of biological concepts and difficulty in applying knowledge to solve practical challenges, with cellular respiration and genetics recognised as particularly troublesome areas (WAEC, 2022). In Katsina State, the Biology pass rate in the 2022 WASSCE was approximately 48%, below the national average (Katsina State Ministry of Basic and Secondary Education [KSMBSE], 2023). Persistent low achievement in Biology not only restricts students' access to Science, Technology, Engineering, and Mathematics (STEM) pathways but also constrains the socio-economic development of the region, signaling an urgent need for pedagogical innovation. Although there is a significant body of literature that ties SRL to academic achievement, few studies have empirically evaluated the causal influence of organised SRL treatments on both motivation and performance concurrently. Recent reviews affirm that while SRL is robustly associated with achievement, interventions that integrate cognitive and motivational components remain relatively rare, and their joint causal mechanisms are underexplored (Theobald, 2021; Dent & Koenka, 2016). Methodologically, many existing studies are correlational or involve short-term laboratory-based designs, limiting their ecological validity. Research on the impact of integrated SRL treatments on long-term learning outcomes in classrooms is limited (de Boer et al., 2018; Dignath & Veenman, 2021). This gap is particularly pronounced in Nigeria, and even more so in northern Nigeria. Existing work in the region has mainly explored correlational relationships among SRL, motivation, and performance (e.g., Garba & Abubakar, 2020), while experimental studies of structured SRL programmes are scarce. A recent review of educational interventions in sub-Saharan Africa further underscores the need for locally adapted, methodologically rigorous studies that move beyond documenting associations to testing causal mechanisms (Stern et al., 2021). In this context, the current quasi-experimental study explores the impact of a self-regulated learning intervention on secondary school students' motivation and academic performance in cellular respiration in Katsina State, Nigeria.

Literature Review

Theoretical Perspectives on Self-Regulated Learning

Several influential models have been proposed to explain how SRL operates and how it can be fostered in classrooms. According to Zimmerman's social cognitive model, SRL occurs in three cyclical phases: forethought (goal setting, strategic planning, and self-efficacy), performance (strategy implementation and self-monitoring), and self-reflection (self-evaluation, causal attributions, and adaptive reactions) (Zimmerman, 2002, 2020). Pintrich's approach highlights the management of cognition, motivation/affect, conduct, and situation through the stages of foresight, monitoring, control, and reflection (Panadero 2017). Boekaerts' dual-processing model distinguishes between a development pathway, in which students work hard to attain learning objectives, and a well-being pathway, in which they safeguard their emotional state, emphasising the importance of motivational and emotional management in SRL (Smit et al., 2019). These models converge in portraying self-regulated learners as those who actively goals setting, selection and adaption strategies, progress monitoring, and reflection on their outcomes to improve subsequent performance. Importantly, they also highlight that SRL can be taught and scaffolded through targeted instructional interventions, rather than treated as an innate trait that students either possess or lack (Dignath & Veenman, 2021). In other words, SRL provides not only a descriptive account of how effective learners operate but also a prescriptive framework for designing classroom interventions.

Self-Regulated Learning and Motivation

Motivation is essential to SRL, since it provides the energy and direction for self-regulatory mechanisms. According to self-determination theory, there are two types of motivation: autonomous (intrinsic motivation and identifiable regulation) and controlled (external and introjected regulation), with autonomous motivation being linked to deeper learning and perseverance. In the setting of SRL, intrinsically driven learners are more likely to adopt personally relevant objectives, persevere in the face of adversity, and participate in metacognitive monitoring (Schunk & DiBenedetto, 2020). Empirical research consistently show a favourable relationship between SRL, motivating beliefs, and engagement. Smit et al. (2019) discovered that motivational techniques such as increasing task value, self-consequating, and environmental structuring influenced the link between students' motivational beliefs and participation in learning. Tanti et al. (2020) found that pupils



Effects of Self-Regulated Learning Intervention on ... Sada, U., Et. al. (2026)

with stronger self-regulation shown increased interest and perseverance in learning science. Saghir and Batool (2019) found substantial positive connections between SRL and motivation among university students, but they also observed gender variations in several motivational characteristics. In science and Biology education, SRL and motivation play a critical role because students often encounter abstract concepts, multiple representations, and complex laboratory activities that demand sustained cognitive effort. When learners lack appropriate strategies, repeated failure can erode their self-efficacy and interest, whereas structured SRL interventions can help them set realistic goals, monitor their understanding, and attribute success to controllable factors such as strategy use (Ekuri & Offiah, 2018; Suhandoko & Hsu, 2020). This is particularly relevant for topics like cellular respiration, where students must integrate microscopic, macroscopic, and symbolic representations to grasp energy transformation in living systems.

Self-Regulated Learning, Academic Performance, and Intervention Research

Meta-analytic evidence provides robust support for the positive association between SRL and academic achievement across educational levels. Dent and Koenka (2016) found medium-sized relationships between SRL components and achievement from infancy through adolescence, while de Boer et al. (2018) showed that interventions incorporating explicit strategy instruction and metacognitive training tend to produce higher impacts on performance than those using on motivation alone. Theobald (2021) reported that SRL training programmes significantly improved university students' grades, especially when interventions were embedded in regular courses rather than delivered as stand-alone workshops. However, several gaps remain. First, many SRL studies are correlational, making it difficult to infer causal effects of SRL training on achievement (Dent & Koenka, 2016). Second, a substantial proportion of intervention studies are conducted in laboratory-like settings with short time frames and small samples, limiting ecological validity (de Boer et al., 2018). Third, relatively few interventions simultaneously target both cognitive such as metacognition, strategy use and motivational like task value and self-efficacy components of SRL in authentic classroom contexts (Dignath & Veenman, 2021). In sub-Saharan Africa, the evidence base is even more limited. Stern et al. (2021) reviewed educational interventions across the region and concluded that relatively few programmes systematically integrated SRL principles into everyday instruction, and even fewer used rigorous quasi-experimental designs with appropriate controls. In Nigeria, Garba and Abubakar (2020) found that self-regulated learning techniques predicted academic progress among senior secondary students, with no significant gender differences, but they did not examine a structured SRL intervention. Ejelue (2017) discovered minor positive associations between SRL skills and Biology success in both male and female students, but did not investigate the causal effect of SRL-based education.

Gender, Self-Regulated Learning, and STEM Achievement

The role of gender in SRL and academic performance has received increasing attention, with varied conclusions. Some studies suggest that female students tend to report higher use of metacognitive and organisational strategies and sometimes higher motivation, while male students may show advantages in particular domains or under certain instructional conditions (Saghir & Batool, 2019). Other studies, particularly in African settings, find minimal or no gender differences in SRL and achievement, especially when instruction is designed to be inclusive and supportive for all learners (Ejelue, 2017; Garba & Abubakar, 2020). In STEM fields, gender disparities in participation and achievement often reflect complex interactions among cultural norms, self-beliefs, teacher expectations, and classroom climate. Interventions that explicitly foster SRL may help mitigate some of these disparities by promoting self-efficacy, mastery goals, and adaptive attributions for both male and female students. Yet, relatively few studies in Nigeria have examined whether SRL interventions produce comparable benefits across gender groups, particularly at the secondary school level in Biology.

Rationale of the Study

Given persistent low achievement in Biology in Katsina State, the strong theoretical and empirical support for SRL, and the limited quasi-experimental evidence from Nigerian classrooms, there is a clear need for locally grounded intervention research. Moreover, understanding whether SRL-based interventions benefit male and female students equally is essential for designing equitable pedagogical strategies. Against this backdrop, the present study implemented a Self-Regulated Learning Intervention integrated into the teaching of cellular respiration and examined its effects on students' motivation and academic performance, as well as potential gender differences in these effects.

Objectives of the Study

The specific objectives of the study are to:



Effects of Self-Regulated Learning Intervention on ... Sada, U., Et. al. (2026)

1. Determine the effect of the Self-Regulated Learning Intervention (SRLI) combined with conventional teaching on students' motivation towards learning cellular respiration.
2. Determine the effect of the Self-Regulated Learning Intervention (SRLI) combined with conventional teaching on students' academic performance in cellular respiration.
3. Examine the influence of gender on the motivation of students taught cellular respiration using the Self-Regulated Learning Intervention (SRLI) combined with conventional teaching.
4. Examine the influence of gender on the academic performance of students taught cellular respiration using the Self-Regulated Learning Intervention (SRLI) combined with conventional teaching

Research Questions

Thus, the following research questions have been raised:

1. What is the mean difference in motivation towards learning cellular respiration between students taught using the Self-Regulated Learning Intervention (SRLI) and conventional method and those taught using the conventional method only?
2. What is the mean difference in academic performance scores between students taught cellular respiration using SRLI and the conventional method and those taught using the conventional method only?
3. What is the mean difference in motivation towards learning cellular respiration between male and female students taught using SRLI and the conventional method only?
4. What is the mean difference in academic performance scores between male and female students taught cellular respiration using SRLI and the conventional method only?

Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

- H₀₁: There is no significant difference in motivation towards learning cellular respiration between students taught with SRLI and the conventional method and those taught using the conventional method only.
- H₀₂: There is no significant difference in academic performance scores in cellular respiration between students taught using SRLI and the conventional method and those taught using the conventional method only.
- H₀₃: There is no significant difference in motivation toward learning cellular respiration between male and female students taught using SRLI and the conventional method
- H₀₄: There is no significant difference in academic performance scores in cellular respiration between male and female students taught using SRLI and the conventional method

Methodology

Research Design

The study used a quasi-experimental, pretest-posttest control group design. A quasi-experimental design was chosen over a true experimental design due to the inherent constraints of conducting research in authentic educational settings, where randomly assigning individual students to conditions is often logistically impractical and ethically questionable because it disrupts intact classroom structures (Shadish et al., 2002). To mimic the rigour of an experiment and boost causal inference, intact classes were randomly assigned to the experimental or control conditions. The pretest-posttest control group approach is considered since it allows for the comparison of changes over time between groups while accounting for pre-existing disparities. The inclusion of a pretest allows for the use of Analysis of Covariance (ANCOVA), which statistically compensates for baseline scores, boosting the precision of the analysis and the validity of findings about the intervention's effect (Field, 2018). This design is regarded as reliable for assessing the efficiency of educational interventions when full randomisation is not possible (Creswell & Creswell, 2018)..

Population, Sampling, and Assignment

The target population comprised all 5,378 Senior Secondary School Year II (SSII) students offering Biology in public schools within Katsina State, Nigeria, during the 2022/2023 academic session. A multi-stage sampling technique was implemented to enhance the representativeness and practicality of the sample. First, two co-educational public secondary schools with comparable characteristics including student academic profiles, teacher qualifications, and laboratory facility access were purposively selected from the same Local Government Area to minimize the influence of extraneous contextual variables. Second, two intact SSII classes from each school were selected via simple random sampling (balloting). Finally,



Effects of Self-Regulated Learning Intervention on ... Sada, U., Et. al. (2026)

one class was assigned randomly to the experimental group (n = 48) while the other was assigned as the control group (n = 37), resulting in a total sample of 85 students. This sampling strategy ensures that the groups are as equivalent as possible prior to the intervention, strengthening the internal validity of the comparison. The use of intact classes preserves ecological validity, ensuring the findings are relevant to typical classroom practice.

Instrumentation

Data were collected using two primary instruments: (1) Motivational Strategies for Learning Questionnaire (MSLQ) The motivation section of the well-established MSLQ (Pintrich et al., 1991) was adapted for this study’s context. The original subscales assessing intrinsic goal orientation, task value, and self-efficacy for learning and performance were adjusted. The language was condensed for secondary school comprehension, and all item examples were linked to the Biology lesson on cellular respiration. This modification is justified to ensure the instrument's content validity and relevance to the specific participant group and study issue. (2) Cellular Respiration Performance Test (CRPT) The researcher created a 30-item accomplishment exam with 25 multiple-choice questions and 5 structured short-answer questions. The exam pattern was designed to coincide with the SSII national curriculum for cellular respiration, testing cognitive areas such as knowledge, understanding, application, and analysis in order to move beyond rote recollection. This instrument is motivated by the necessity for a domain-specific, curriculum-aligned assessment of the particular academic concept being investigated.

Validity and Reliability of the Instruments

To assure validity, the instruments were evaluated by a panel of three specialists in scientific education, educational psychology, and test measurement. Their suggestions for item clarity, relevance, coverage, and suitability for the intended audience were incorporated into the final editions. A pilot research included 30 SSII Biology students from a non-participating school. Cronbach's alpha analysis indicated reliability values of.859 for the modified MSLQ and.816 for the CRPT. These coefficients imply good to exceptional internal consistency, confirming the instruments' dependability for research usage (DeVellis, 2017).

Data Analysis Techniques

The data were analysed with the Statistical Package for the Social Sciences (SPSS) version 23. Descriptive statistics (means and standard deviations) were used to summarise the data and respond to the four research questions on mean differences. For hypothesis testing, Analysis of Covariance (ANCOVA) was employed. The use of ANCOVA is strongly justified, as it tests for differences between groups on the post-test scores while statistically controlling for any pre-intervention differences captured by the pretest scores. This control increases the sensitivity of the test and reduces error variance, providing a more powerful and accurate assessment of the intervention’s true effect on the dependent variables (motivation and academic performance) after accounting for initial ability levels (Pallant, 2020). This analytical approach aligns with best practices for analysing pretest-posttest control group designs in educational studies.

Presentation of Results

Research Question One: What is the mean difference in motivation towards learning cellular respiration between students taught using SRLI and conventional method and those taught using the conventional method only?

Table 1:

Means and Standard Deviations of Motivation Levels of Students toward Cellular Respiration in Experimental and Control Groups

Groups	N	M	SD	MD
SRLI (EG)	48	70.27	5.59	
Conventional Method (CG)	37	58.43	11.20	11.84

M = Mean, SD = Standard Deviation, MD=Mean Difference

Table 1 shows that students taught using SRLI recorded a higher mean motivation score (M = 70.27, SD = 5.59) than those taught with the conventional method (M = 58.43, SD = 11.20), with a mean difference of 11.84 in the favour of the experimental group. This suggests that the SRLI substantially enhanced students’ motivation toward learning cellular respiration compared with the conventional approach alone.



Effects of Self-Regulated Learning Intervention on ... Sada, U., Et. al. (2026)

Research Question Two: What is the mean difference in academic performance scores between students taught cellular respiration using SRLI and conventional method and those taught using the conventional method only?

Table 2:

Means and Standard Deviations of Academic Performance Scores of Students in Cellular Respiration in Experimental and Control Groups

Groups	N	M	SD	MD
SRLI (EG)	48	14.35	2.03	
Conventional Method (CG)	37	11.32	3.30	3.03

M = Mean, SD = Standard Deviation, MD=Mean Difference

Table 2 indicates that students exposed to SRLI achieved a higher mean academic performance score (M = 14.35, SD = 2.03) than those taught using the conventional method (M = 11.32, SD = 3.30), with a mean difference of 3.03. This demonstrates that SRLI is more effective than the conventional method in improving students' academic performance in cellular respiration.

Research Question Three: What is the mean difference in motivation towards learning cellular respiration between male and female students taught using SRLI and conventional method only?

Table 3:

Means and Standard Deviations of Motivation Levels of Male and Female Students toward Cellular Respiration in Experimental Group only

Gender	N	M	SD	MD
Male	28	70.43	5.01	0.38
Female	20	70.05	6.50	

M = Mean, SD = Standard Deviation, MD=Mean Difference

Table 3 shows that male students in the experimental group had a mean motivation score of 70.43 (SD = 5.01), while female students had a mean score of 70.05 (SD = 6.50), resulting in a mean difference of 0.38 in favour of males. This difference is small, indicating that SRLI produced comparable motivation levels for both male and female students.

Research Question Four: What is the mean difference in academic performance scores between male and female students taught cellular respiration using SRLI and conventional method only?

Table 4:

Means and Standard Deviations of Academic Performance Scores of Male and Female Students in Cellular Respiration in Experimental Group Only

Gender	N	M	SD	MD
Male	28	14.25	2.34	0.22
Female	20	14.43	1.81	

M = Mean, SD = Standard Deviation, MD=Mean Difference

Table 4 indicates that male students had a mean score of 14.25 (SD = 2.34), while female students had a mean score of 14.43 (SD = 1.81), yielding a mean difference of 0.22 in favour of females. The very small difference suggests that SRLI supports similar levels of academic performance for both male and female students.

Hypotheses Testing

Motivation (H₀₁ & H₀₃)

Table 5:

Analysis of Covariance for Motivation Scores by Group and Gender

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3440.983 ^a	4	860.246	14.543	.000
Intercept	2974.556	1	2974.556	50.288	.000
Pretest	178.427	1	178.427	3.016	.086
Groups	3042.697	1	3042.697	51.440	.000
Group * Gender	117.027	1	117.027	1.978	.163
Gender	77.031	1	77.031	1.302	.257
Error	4732.029	80	71.332		



Effects of Self-Regulated Learning Intervention on ... Sada, U., Et. al. (2026)

Total	362375.000	85
Corrected Total	8173.012	84

An ANCOVA was conducted on posttest motivation scores, with pretest motivation as the covariate. After adjusting for pretest scores, there was a statistically significant main effect of instructional group on motivation, $F(1, 80) = 51.44$, $p < .001$, indicating that students in the experimental group reported higher motivation than those in the control group; therefore, H_{01} was rejected. The Group \times Gender interaction, $F(1, 80) = 1.98$, $p = .163$, and the main effect of gender, $F(1, 80) = 1.30$, $p = .257$, were not significant. Thus, H_{03} was retained.

Academic Performance (H_{02} & H_{04})

Table 6:

Analysis of Covariance for Academic Performance Scores by Group and Gender

Source	Type III Squares	Sum of Df	Mean Square	F	Sig.
Corrected Model	198.387 ^a	4	49.597	6.882	.000
Intercept	885.074	1	885.074	122.819	.000
Pretest	1.629	1	1.629	0.226	.636
Groups	184.995	1	184.995	25.671	.000
Group * Gender	3.407	1	3.407	0.473	.494
Gender	0.761	1	0.761	0.106	.746
Error	576.507	80	7.206		
Total	15218.000	85			
Corrected Total	774.894	84			

An ANCOVA was conducted on post-test academic performance scores, with pre-test performance as the covariate. After controlling for pre-test differences, a statistically significant main effect of instructional group was found, $F(1, 80) = 25.67$, $p < .001$, indicating higher achievement for students in the SRLI group compared to those in the conventional group; thus, H_{02} was rejected. The Group \times Gender interaction, $F(1, 80) = 0.47$, $p = .494$, and the main effect of gender, $F(1, 80) = 0.11$, $p = .746$, were not significant; therefore, H_{04} was retained.

Discussion of Findings

The results of this study show that SRLI had a statistically significant, favourable influence on students' motivation to learn Biology, specifically cellular respiration, when compared to the conventional technique. This is consistent with past research by Tanti et al. (2020) and Saghir and Batool (2019), which found substantial positive relationships between self-regulation and student motivation. The intervention's efficacy can be ascribed to SRL tactics like as goal planning, self-monitoring, and self-reflection, which actively involve learners and foster more ownership of learning, thereby improving intrinsic motivation. The study also found that SRLI resulted in much better academic achievement in cellular respiration than the standard technique. This is consistent with the findings of Ekuri and Offiah (2018), who found a substantial association between self-regulatory qualities and academic success, and Suhandoko and Hsu (2020), whose intervention enhanced undergraduate accomplishment. SRLI promotes strategic, reflective learning over rote memorisation, allowing students to gain deeper conceptual knowledge, which results into improved exam scores. However, the positive effect on performance differs somewhat from the findings of Younes Doostian et al. (2015), who observed gains in achievement motivation but not in science test scores, indicating that the design and integration of SRLI in this study were particularly effective in converting motivational gains into measurable achievement. In terms of gender, there are no significant variations in motivation or performance, in contrast to Saghir and Batool (2019), who found gender disparities in self-regulation and motivation at the university level. Instead, the current findings are similar with Ejelue (2017), who found low positive associations between SRL and success in both males and females, with no significant gender differences. This implies that, in the setting of Katsina State secondary schools, SRLI functioned as a gender-neutral teaching instrument that helped learners equally.

Conclusion

Based on the empirical findings, the study finds that SRLI is a very successful pedagogical technique for teaching complex biology concepts like cellular respiration. When compared to standard teaching methods, the intervention dramatically increased students' motivation, self-efficacy, and academic achievement. Importantly, the effects were equal for both male and female students, demonstrating that SRLI is gender-friendly and inclusive. SRLI shows tremendous promise for



Effects of Self-Regulated Learning Intervention on ... Sada, U., Et. al. (2026)

enhancing scientific learning results in Katsina State and comparable contexts since it transforms students from passive users of knowledge to active, self-directed learners.

Recommendations

Based on the findings, the following recommendations are proposed:

1. Biology teachers at the secondary school level should systematically incorporate SRLI strategies (e.g., goal setting, self-monitoring, and self-evaluation) into their lesson plans for complex topics such as cellular respiration and genetics.
2. Ministries of education and professional bodies, such as the Science Teachers Association of Nigeria (STAN), should organize regular workshops and in-service training to build teachers' capacity to design and implement SRL-based instruction.
3. Educational policymakers in Katsina State and beyond should provide curricular and assessment guidelines that explicitly encourage SRL practices and allocate resources for scaling up evidence-based interventions like SRLI across schools.

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