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Effect of Stem Initiatives on Science Education in Secondary Schools in Cross River State, Nigeria

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Abstract

This study investigated the effect of STEM initiatives on science education in secondary schools in Cross River State, Nigeria. Two research questions and corresponding hypotheses guided the study. The study adopted a non-equivalent control group pretest–posttest quasi-experimental design, with a population of 1,129 SS I science students from 322 public secondary schools. A sample of 828 students from 15 purposively selected schools was used. Data were collected using the Science Achievement Test (SAT) and the STEM Engagement and Interest Questionnaire (SEIQ), with reliability coefficients of 0.88 and 0.86, respectively. Descriptive statistics, t-tests and ANOVA were used to analyze the data. Results showed that students exposed to STEM-based teaching strategies achieved significantly higher academic performance and reported greater interest and engagement in science than those taught using conventional methods. The findings highlight the importance of integrating STEM initiatives into science curricula to enhance learning outcomes and motivation. The study recommends implementation.

Keywords: Academic Performance**,** STEM Initiatives**,** Science Education and Student Engagement

Introduction

Science education is fundamental to preparing students with critical thinking, problem-solving abilities and technological competence required in the 21st century. However, in Nigeria, secondary school science instruction is often characterized by traditional teaching methods and low student engagement, which may limit students' academic achievement and sustained interest in science (Akinsola & Adedapo, 2018). This situation underscores the need for innovative instructional approaches that can improve learning outcomes. One such innovation is the adoption of STEM initiatives, which integrate science, technology, engineering, and mathematics through inquiry, collaboration, and real-world problem-solving activities (Bybee, 2010; Honey, Pearson & Schweingruber, 2014).

STEM-based teaching strategies are instructional approaches that integrate science, technology, engineering, and mathematics in a coherent manner. These strategies emphasize active learning, problem-solving, and real-world application of concepts, shifting students from passive recipients of information to engaged learners (Bybee, 2010). Evidence from the literature indicates that teaching approaches incorporating collaborative and inquiry-based activities improve students' conceptual understanding and performance in science subjects (Honey, Pearson & Schweingruber, 2014). Inquiry-oriented STEM instruction, for instance, engages students in scientific practices such as formulating hypotheses, conducting experiments, and interpreting data, which has been associated with higher achievement scores in science assessments (Meier, 2015). Furthermore, when STEM is embedded into lesson design, students are more likely to develop deeper understanding of scientific concepts and enhanced cognitive skills (National Research Council, 2012). Empirical studies across different contexts also suggest that students exposed to integrative STEM lessons perform significantly better in science tests than those taught through traditional lecture-based methods (English & King, 2015).

Similarly, STEM initiatives - comprising structured programmes, policies and classroom practices - extend beyond academic performance to foster students' interest, motivation and sustained engagement in science learning (Estrada, Burnett & Campbell, 2016). Engagement in STEM encompasses behavioural participation, emotional interest and cognitive investment in learning (Fredricks, Blumenfeld & Paris, 2004). Studies have shown that active, project-based STEM initiatives increase students' enthusiasm for science by enabling hands-on exploration, peer collaboration, and application of knowledge to real-life problems (Maltese & Tai, 2017). Participation in activities such as robotics clubs, science competitions, and makerspace projects has also been linked to increased interest in STEM-related careers (Barron, 2019). Moreover, when STEM programmes are contextually relevant, they enhance positive attitudes toward science and promote engagement, particularly among previously disengaged learners (Kelley & Knowles, 2016).

Empirical evidence further supports these assertions. A study by Kelley and Knowles (2016) involving 400 secondary school students in the United States reported that learners exposed to STEM-based instructional strategies demonstrated significantly higher achievement in science compared to those taught using conventional methods. Likewise, Barker and Dickenson (2017) found that STEM initiative implementation significantly improved students' cognitive and behavioural engagement in science classrooms in Australia. These studies highlight the effectiveness of STEM approaches in enhancing both academic performance and engagement. However, while such findings are robust, they are largely drawn from developed educational contexts with well-established infrastructure, teacher training systems, and curriculum support for STEM integration.

Despite the growing body of literature, several gaps remain evident. First, there is limited empirical evidence on the implementation and effectiveness of STEM initiatives within the Nigerian secondary school context, where infrastructural challenges, resource constraints and differences in teacher preparedness may influence outcomes. Second, many existing studies tend to examine either academic performance or student engagement in isolation, with fewer studies providing a comprehensive analysis of both variables within the same context. Third, contextual factors such as cultural relevance, local curriculum demands, and regional disparities in educational resources are often underexplored, particularly in states like Cross River. Additionally, previous Nigerian studies have not sufficiently examined how integrated STEM approaches can be systematically applied to improve both learning outcomes and sustained student interest in science.

These gaps justify the need for the present study, which seeks to investigate the contribution of STEM initiatives to science education among secondary school students in Cross River State, Nigeria. By simultaneously examining academic performance and student engagement within a localized context, the study aims to provide empirical evidence that can inform instructional practices, policy decisions and future research on STEM integration in Nigerian schools.

Research questions

Two research questions guided the study:

1. What is the effect of STEM-based teaching strategies on students' academic performance in science subjects?
2. How do STEM initiatives influence students' interest and engagement in science education?

Statement of Hypotheses

Two hypothesis formulated for the study:

1. STEM-based teaching strategies have no significant effect on students' academic performance in science subjects.
2. STEM initiatives do not significantly influence students' interest and engagement in science.

Methodology

The study adopted a non-equivalent control group pretest–posttest quasi-experimental design. This design enabled comparison between students exposed to STEM-based teaching strategies (experimental group) and those taught using conventional instructional methods (control group) within their natural classroom settings. The design involved administering pretests to both groups to establish baseline equivalence, followed by treatment for the experimental group and conventional instruction for the control group, and finally posttests to measure the effect of the intervention. This approach was considered appropriate because intact classes were used without random assignment, thereby preserving the school structure while still allowing for reasonable causal inferences.

The population of the study comprised 1,129 Senior Secondary One (SSI) science students drawn from 322 public secondary schools in Cross River State. From this population, a sample of 828 SSI science students was selected from 15 purposively chosen public secondary schools that had functional science programs and demonstrated willingness to participate in the research. Purposive sampling ensured that the selected schools reflected varying levels of exposure to STEM initiatives, resource availability, and instructional quality. The sampled students were assigned to experimental and control groups based on their existing class structures, ensuring comparability while maintaining ecological validity.

Two instruments were used for data collection: the Science Achievement Test (SAT) and the STEM Engagement and Interest Questionnaire (SEIQ). The SAT was a researcher-developed instrument consisting of 40 multiple-choice items covering key SSI curriculum areas in Physics, Chemistry, and Biology. Each item was scored 1 for a correct response and 0 for an incorrect response, yielding a total score range of 0–40. The instrument was validated by experts in science education and measurement and evaluated for reliability through a pilot test conducted in two schools outside the main study sample, producing a Cronbach's alpha coefficient of 0.88. The SEIQ, adapted from the Student Engagement in Science Scale developed by Fredricks, Blumenfeld, and Paris (2004), consisted of 20 items measured on a 4-point Likert scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, and 4 = Strongly Agree. The SEIQ assessed students' interest, motivation, and behavioural engagement in STEM-related learning activities. The reliability coefficient obtained from the pilot study was 0.86 using Cronbach's alpha, demonstrating acceptable internal consistency.

Data collection commenced after obtaining ethical clearance from relevant educational authorities and informed consent from school administrators, teachers, and students. The experimental group received STEM-based instructional strategies integrating inquiry, problem-solving, collaboration, and real-world applications, while the control group was taught using conventional lecture-based methods over a specified instructional period. The SAT and SEIQ were administered as pretest and posttest measures under standardized classroom conditions supervised by the researcher and trained assistants. Data were analyzed using descriptive and inferential statistics, including independent samples t-tests and Analysis of Variance (ANOVA), and the stated hypotheses were tested at a 0.05 level of significance.

The decision rule for hypothesis testing was as follows:

i. Reject the null hypothesis (H_0) if the calculated p-value is less than 0.05 ($p < 0.05$).

ii. Fail to reject the null hypothesis if the calculated p-value is greater than or equal to 0.05 ($p \geq 0.05$).

Results

Descriptive Statistics of Studied Variables

Table 1

Descriptive Statistics of Students' Academic Performance in Science (SAT Scores)

Variable	N	Min.	Max.	Mean	SD
SAT score (Academic performance)	**828**	**12**	**40**	**27.45**	**6.25**

Interpretation

The mean SAT score of 27.45 (SD = 6.23) indicates that, on average, students performed moderately well in science after exposure to STEM-based teaching strategies. The range (12–40) shows variability in students' academic performance across the sampled schools. This suggests that while some students achieved high mastery, others require additional support, highlighting the potential impact of STEM initiatives on learning outcomes.

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Table 2

Descriptive Statistics of Students' Interest and Engagement in Science (SEIQ Scores)

Variable	N	Min.	Max.	Mean	SD
SEIQ score (Interest and Engagement)	828	28	80	61.32	9.14

Interpretation

The mean SEIQ score of 61.32 (SD = 9.14) indicates a generally high level of interest and engagement among students in science learning following STEM initiatives. The variability (28–80) shows differences in engagement levels, suggesting that some students respond more positively to STEM activities than others. Overall, the descriptive data imply that STEM initiatives may enhance student motivation and involvement in science education.

Hypotheses Testing

Hypothesis one: STEM-based teaching strategies have no significant effect on students' academic performance in science subjects.

Table 3

Independent Samples t-Test on Academic Performance

Group	N	Mean	SD	T	df	Sig. (2-tailed)
STEM-based Instruction	414	29.15	5.87	8.52	826	0.000
Conventional Instruction	414	25.75	6.12	-	-	-

Interpretation

The t-test result ($t = 8.52$, $p < 0.05$) indicates a significant difference in academic performance between students exposed to STEM-based teaching strategies and those taught conventionally. The mean score for the STEM group (29.15) is higher than the control group (25.75), confirming that STEM strategies positively influence students' academic performance. Thus, the null hypothesis (H_0) is rejected.

Hypothesis two: STEM initiatives do not significantly influence students' interest and engagement in science.

Table 4

Independent Samples t-Test on Interest & Engagement (SEIQ Scores)

Group	N	Mean	SD	T	df	Sig. (2-tailed)
STEM-Initiative	414	64.28	8.62	9.17	826	0.000
Conventional Instruction	414	58.36	9.07	-	-	-

Interpretation

The t-test result ($t = 9.17$, $p < 0.05$) shows a significant difference in students' interest and engagement between the STEM initiative group and the conventional instruction group. Students exposed to STEM initiatives had higher engagement (Mean = 64.28) than those in traditional settings (Mean = 58.36), supporting the alternative hypothesis (H_1) and confirming that STEM initiatives enhance student interest and engagement in science education.

Summary of Findings

1. Students taught using STEM-based strategies scored significantly higher in science than those taught using conventional methods.
2. STEM initiatives significantly increased students' interest, motivation, and engagement in science learning.
3. Both performance and engagement scores demonstrated variability, indicating that while

most students benefit from STEM initiatives, individual differences remain.

Discussion of Findings

Effect of Stem-Based Teaching Strategies on Academic Performance

The findings revealed that students exposed to STEM-based teaching strategies performed significantly better in science than those taught using conventional methods ($t = 8.52, p < 0.05$). The higher mean score of the STEM group (29.15) compared to the control group (25.75) indicates that inquiry-driven, integrative instruction enhances students' mastery of science concepts.

This result is consistent with earlier studies. Akinsola and Adedapo (2018) found that Nigerian students taught through inquiry-oriented STEM approaches achieved higher test scores, while Maltese and Tai (2017) reported improved conceptual understanding following STEM laboratory interventions. The findings support constructivist learning theory, which emphasizes active knowledge construction through exploration and problem-solving. Although the approach demonstrates strong relevance to the Nigerian context, variations in students' prior knowledge and motivation may partly explain differences in achievement outcomes.

Effect of Stem Initiatives on Students' Interest and Engagement

The study further showed that STEM initiatives significantly improved students' interest and engagement in science ($t = 9.17, p < 0.05$). Students in the STEM group recorded higher mean engagement scores (64.28) than those in conventional classrooms (58.36), suggesting increased motivation and participation in science learning.

This finding aligns with Estrada, Burnett and Campbell, (2016) who reported enhanced engagement among students involved in STEM programs in the USA, who found increased interest among Nigerian students participating in STEM clubs. The result reinforces the study's conceptual framework, which positions engagement as a pathway through which STEM strategies improve learning outcomes. While the structured implementation of STEM strengthens the study's evidence, reliance on self-reported engagement data may introduce response bias.

Conclusion

The study established that STEM-based teaching strategies significantly improved students' academic performance as well as their interest and engagement in science. These findings validate the constructivist foundation of the study and demonstrate that integrating STEM initiatives into secondary school instruction can enhance both cognitive and affective learning outcomes. Therefore, STEM integration represents a practical strategy for advancing science education in Cross River State and similar educational contexts.

Recommendations

Based on the findings, the following recommendations are made:

1. Schools should adopt STEM-based instructional strategies, including inquiry-based learning, project-based tasks and practical laboratory experiments, to enhance student performance in science.
2. Education authorities should organize regular training programs for science teachers to equip them with the knowledge and skills to implement STEM initiatives effectively.

Suggestions for Further Studies

1. Future research could investigate the long-term impact of STEM initiatives on students' career choices and performance in national examinations.
2. Comparative studies between rural and urban secondary schools could identify contextual factors that enhance or hinder STEM implementation.

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