



Effect of Critical Exploration Strategy on Students' Academic Achievement in Basic Science in Makurdi, Benue State

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Abstract

This study examined the effectiveness of the critical exploration strategy in enhancing academic achievement in Basic Science among Upper Basic Two students in Makurdi, Benue State. Using a quasi-experimental pretest-posttest control group design, a sample of 74 students (41 males, 33 females) was drawn from a population of 12,703. Data were collected using the Basic Science Achievement Test, which had a reliability index of 0.92 (K-R20). The study lasted six weeks and employed critical exploration for the experimental group and the discussion method for the control group. Mean, standard deviation, and ANCOVA were used for analysis. Results showed a significant improvement in students' achievement using the critical exploration strategy compared to the discussion method ($F(2,71) = 308.853$, $p < 0.05$). No significant differences were found based on gender ($F_{2,30} = 2.460$; $P=0.127 > 0.05$) or interaction between strategy and gender ($F_{4,69} = 0.000$; $P=0.998 > 0.05$). The study concluded that critical exploration effectively improves achievement and recommended its adoption in Basic Science instruction.

Key Words: Academic Achievement, Basic Science, Basic Education, Creative Thinking and Critical Exploration.

Introduction

Globally education especially science education has been perceived as the cornerstone for social, economic and technological development. This is why nations strive to advance scientific knowledge and skills. In Nigeria, science education is intended to foster literacy, skills acquisition, technological advancement and help citizens harness human and material resources to achieve developmental goals of the nation (Federal Republic of Nigeria, FRN, 2014). This implies that the Nigerian government places a high priority on science and technology education as a key means of developing scientific knowledge, skills, and competencies. Agbidye and Achor (2015) stressed the need for scientifically skilled individuals for Nigeria to remain globally competitive. Recently, Kpiranyam et al. (2024) highlighted the transformative power of scientific knowledge and its role in solving national problems. This explain the inclusion of subjects in the Nigerian science curriculum, like Basic Science and Technology, Biology, Chemistry, and Physics.

Basic Science, taught at the basic education level in Nigeria, is an introductory subject that combines elements of Biology, Chemistry, Physics, and

Earth/Space Science. According to Jirgba et al. (2019), it equips learners with foundational scientific knowledge and skills essential for survival, sustainability, active learning, and societal development. The subject encourages curiosity and hands-on learning through activities like observing objects, classifying materials, and conducting simple experiments (Olagunju & Animasahun, 2016).

Despite its importance to Nigeria's scientific and technological development, students' performance in Basic Science at the Basic Education Certification Examination (BECE) has been inconsistent. Studies (Agu & Samuel, 2018; Ajio et al., 2023; Agbidye et al., 2024) report persistently low achievement, suggesting that many students struggle to understand and respond to Basic Science concepts. This trend has raised concerns among stakeholders, including parents, educators, policymakers, and the government. Although attempts have been made to improve learners' academic achievement especially by adopting strategies like Education For All (EFA), National Economic Empowerment Development Strategies (NEEDS) and Sustainable Development Goals (SDGs), training and

organization of workshops for teachers in Nigeria and Benue State, students' achievement in Basic Science in Benue State is still inconsistent. For instance, from 2020-2023, only in the 2019/2020 and 2021/2022 were 50% of Basic Science students who sat for BECE able to pass (BECE, 2020- 2023).

Several scholars have examined how instructional strategies affect students' achievement in Basic Science, noting that reliance on conventional methods, such as lectures, textbook-based discussions, and rote memorization, contributes to low performance (Eriba & Samuel, 2018; Odoh & Apine, 2019; Agbidye et al., 2023). These methods often neglect critical thinking and real-life application of concepts. To align with 21st-century educational demands, researchers (Hamilton & Telu, 2017; Kpiranyam, 2021) advocate for innovative, learner-centered strategies that promote active engagement, exploration, and hands-on learning. One such effective strategy is critical exploration, which encourages deeper understanding and practical application of scientific knowledge.

Critical Exploration is an inquiry-based teaching and learning strategy that promotes active engagement, questioning, and problem-solving to help students develop deeper understanding and critical thinking skills, either independently or collaboratively. Löfgren et al. (2013) view critical exploration as open-ended inquiry with the focusing on the exploration of students' questions related to specific content topics. Hamdan (2020) opine that with the critical exploration teachers can help students study science by applying scientific inquiry skills. This strategy is grounded in constructivist learning theory, which suggests that learners build knowledge through experience, reflection, and interaction with their surroundings. The learners may exercise curiosity, actions, observations, conjectures and thought. To Fitzgerald and Smith (2016) the students are guided by the teacher to examine diverse controversial topics and scenarios, sharpen critical thinking skills, participate in dynamic collaborative learning as they learn science. This could enhance their achievement in Basic science. Ajayi et al. (2020) argued that the exploration of science helps learners develop the ability to actively plan, engage in learning, interpret information, draw inferences, and report the outcomes of their learning activities. Such a learning environment, as Ayua (2019) noted, fosters learners' curiosity, helps them make connections, and encourages them to take ownership of their learning.

The main features of critical exploration strategy involve student-centered learning, questioning

and inquiry, hands-on activities, collaborative learning, reflection and metacognition and exploration of multiple perspectives. In the opinion of Gkorezis et al. (2017), engaging in exploration helps students enhance their knowledge and skills. Critical exploration plays a vital role in inquiry-based science education, as it gives students hands-on experiences that strengthen their analytical skills and deepen their understanding of scientific concepts (Kotsis, 2024). The author argues that active engagement in science learning not only boosts students' knowledge but also equips them with essential skills for future success. Engaging in hands-on tasks that require observation, analysis, and evidence-based conclusions helps students sharpen their critical thinking and creative problem-solving abilities, potentially improving their achievement in Basic Science. A strategy like critical exploration is desirable as there are reports that students in Makurdi metropolis have low critical thinking abilities (Samba et al., 2021; Kpiranyam et al., 2024).

In various parts of the world, evidence suggests that the critical exploration strategy can improve student learning outcomes ((Huang et al., 2021; Strat et al., 2023; Rahman et al., 2025). In Nigeria, Adeyemi (2018) found that students taught through inquiry-based approaches outperformed their peers in science subjects. Likewise, Okeke (2020) reported enhanced critical thinking and problem-solving skills among students engaged in active learning methods. However, there is limited empirical research on the effectiveness of the critical exploration strategy in improving Basic Science achievement within the study area, particularly with respect to gender differences.

Worldwide, gender is recognized as a factor influencing science education, particularly in Basic Science. Ezebuilo (2020) defines gender as the societal roles assigned to males or females, or as an individual's personal understanding of themselves in terms of their identity. This may have implication in learners' achievement in Basic Science. Researchers (Bamidele & Ariyo, 2017; Hartnett, 2017) have noted that few females participate in science and related subjects. Research reports (Odoh & Apine, 2019; Agbidye et al., 2019; Ajayi et al., 2020; Omega & Kpiranyam, 2024) found that gender difference was leveled out with use of innovative instructional strategy. Given the mixed findings in previous research, this study investigates the impact of the critical exploration strategy on students' achievement in Basic Science in Benue State. While evidence suggests this strategy benefits both male and female students in science education generally, there is

limited research on its specific effects in Basic Science within this region. This study also explores how gender may interact with the strategy to influence academic outcomes.

Research Questions

Three research questions guided the study as follows:

1. What is the difference in the mean achievement scores of students taught Basic Science using critical exploration strategy and those taught using lecture method?
2. What is the difference in the mean achievements cores of male and female students taught Basic Science using critical exploration strategy?
3. What is the interaction effect of strategy and gender on students' achievement in Basic Science?

Hypotheses

Three hypotheses were formulated and tested at 0.05 level of significance as follows:

1. There is no significant difference in the mean achievement scores of students taught Basic Science using critical exploration strategy and those taught using the lecture method.
2. There is no significant difference in the mean achievement scores of male and female students taught Basic Science using critical exploration strategy.
3. There is no significant interaction effect of strategy and gender on students' achievement in Basic Science.

Research Method

The study utilized a quasi-experimental design, specifically a pretest-posttest control group approach. This design was selected for its capacity to evaluate intervention effectiveness by working with groups that have pre-existing characteristics (Achimugu et al., 2024). It was appropriate because random assignment was not possible due to practical limitations, leading to the use of intact classes from the sampled schools.

Population, Sample and Sampling Techniques

The population consisted of 12,703 (6,680 males and 6,023 females) Upper Basic Two Basic Science students from 254 public Basic schools in Benue State (Benue State Universal Basic Education Board, 2025). The sample comprised 74 (41 males and 31 females) Upper Basic Two (SS II) students offering Basic

Science. A multi-stage sampling technique was employed in the sampling procedures. Firstly, purposive sampling technique was used to select two senatorial district from the three in Benue State. This was because of factors such as the presence of schools implementing the critical exploration strategy, diversity in student population, and accessibility for effective data collection. Second, using simple random sampling technique by toss of coin, one LGA was selected from each of the two selected LGAs. Third, one school was randomly selected in each of the local government area. The schools were co-educational to cater for gender variable. The researchers contacted schools directly to verify their enrollment policies regarding gender composition. Fourth, simple random sampling technique by lucky dip was used in assigning one arm in each school to the one experimental groups and the control group.

Instrument for Data Collection

The Basic Science Achievement Test was developed by the researchers using content from Basic Science textbooks. The test consists of two sections: Section A, which collects students' gender information, and Section B, which includes 40 multiple-choice questions, each with four options labeled A to D. The test is scored out of 40, with one mark awarded for each correct response. The items are evenly distributed across the topics of energy, force, and matter, aligned with the lesson objectives through a table of specifications. These core concepts are commonly featured in Basic Science curricula and were scheduled for instruction during the study period according to the scheme of work.

Validation and Reliability of the Instrument

The instrument underwent face and content validation by two Basic Science experts and one Test and Measurement specialist from the Departments of Science and Mathematics Education and Educational Foundations at Benue State University, Makurdi, Nigeria. Their feedback, which addressed grammar, sentence structure, and weak distractors, was incorporated to enhance the instrument's quality. To assess reliability, the Basic Science Achievement Test (BSAT) was administered to 33 Upper Basic Two students in an intact class outside the study sample. The test scores were analyzed using the Kuder-Richardson Formula 20 ($K-R_{20}$), resulting in a reliability coefficient of 0.92, indicating high reliability.

Method of Data Collection

The researchers visited the two selected schools, obtained permission from the principals, and trained two Basic Science teachers as research assistants. The study spanned six weeks, beginning with a pre-test in the first week. Teaching commenced in the second week and continued for four weeks. In the experimental group, students were taught using a lesson plan designed to promote critical exploration, encouraging deep, reflective, and analytical thinking about energy, force, and matter. Students were prompted to think critically, respond to open-ended questions, engage in discussions, and examine concepts from multiple perspectives. The control group received instruction on the same content through traditional lecture-based

lesson plans. All students took the same post-test during the sixth week. Participants, in their intact classes, were randomly assigned to either the experimental or control group and were taught by their regular teachers. To reduce test-wiseness on the post-test, the Basic Science Achievement Test items were rearranged.

Method of Data Analysis

Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was employed at a 0.05 level of significance to test the study's null hypotheses. A null hypothesis was rejected if the p-value was less than or equal to 0.05; otherwise, it was not rejected.

Results

The results are presented in tables below:

Research Question One

Table 1: Mean and Standard Deviation of Achievement Scores of Students Taught Basic Science using Critical Exploration Strategy and those Taught using Lecture Method

Group	n	Pre- Test		Post- Test		Mean Gain
		\bar{x}	SD	\bar{x}	SD	
Critical Exploration	33	22.55	3.73	34.27	3.23	11.72
Lecture	41	22.95	3.91	26.07	3.66	3.12
Mean Difference		0.40		8.20		8.60

Table 1 shows that students taught Basic Science using the critical exploration strategy had pre-test and post-test mean scores of 22.55 and 34.27, with standard deviations of 3.73 and 3.23, respectively. In contrast, students taught using the lecture method scored 22.95 and 26.07 on the pre-test and post-test,

with standard deviations of 3.91 and 3.66. The results indicate a mean gain of 11.72 for the critical exploration group, compared to a mean gain of 3.12 for the lecture group, yielding a mean gain difference of 8.60 in favor of the critical exploration strategy.

Hypothesis One

Table 2: ANCOVA Result for Achievement Scores of Students Taught Basic Science using Critical Exploration Strategy and Those Taught Using Lecture Method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1797.955 ^a	2	898.977	210.902	.000	.856
Intercept	359.249	1	359.249	84.281	.000	.543
Pre-Test	568.686	1	568.686	133.415	.000	.653
Group	1316.496	1	1316.496	308.853	.000	.813
Error	302.640	71	4.263			
Total	67506.000	74				
Corrected Total	2100.595	73				

Table 2 shows that $F(2, 71) = 308.853$; $p = 0.000 < 0.05$, indicating a statistically significant difference. Therefore, the null hypothesis is rejected. This suggests a significant difference in the mean achievement scores between students taught Basic Science using the critical exploration strategy and those

taught by the lecture method. The R^2 value of 0.813 for the combined effect of teaching technique and gender indicates that 81.3% of the variance in students' achievement scores is explained by these factors, reflecting a very large effect size.

Research Question Two

Table 3: Mean and Standard Deviation of Achievement Scores of Male and Female Students Taught Basic Science using Critical Exploration Strategy

Group	Pre- BPST		Post- BPST		Mean Gain
	n	\bar{x}	SD	\bar{x}	SD
Male	18	22.83	3.55	34.83	3.55
Female	15	22.20	4.02	33.60	2.77
Mean Difference		0.63		1.23	
					0.60

Table 3 indicates that male students taught Basic Science using the critical exploration strategy had pre-test and post-test mean scores of 22.83 and 34.83, with standard deviations of 3.55 for both tests. Their female counterparts scored 22.20 and 33.60 on the pre-

test and post-test, with standard deviations of 4.02 and 2.77, respectively. The mean gain for male students was 12.00, compared to 11.40 for female students, resulting in a mean gain difference of 0.60 in favor of males taught using the critical exploration strategy.

Hypothesis Two

Table 4: ANCOVA Result for Mean Achievement Scores of Male and Female Students Taught Basic Science using Critical Exploration Strategy

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	280.374 ^a	2	140.187	77.635	.000	.838
Intercept	235.234	1	235.234	130.272	.000	.813
Pre-Test	267.929	1	267.929	148.378	.000	.832
Gender	4.443	1	4.443	2.460	.127	.076
Error	54.171	30	1.806			
Total	39097.000	33				
Corrected Total	334.545	32				

Table 4 shows that $F(2,30) = 2.460$ with a p-value of 0.127, which is greater than 0.05, indicating that the observed difference is not statistically significant. Therefore, the null hypothesis is retained. This suggests that there is no significant difference in the average achievement scores between male and

female students taught Basic Science using the critical exploration strategy. Additionally, the R-squared value of 0.076 for the combined effect of techniques and gender indicates that only 7.6% of the variance in students' test scores can be explained by gender, reflecting a very small effect size.

Research Question Three

What is the interaction effect of strategy and gender on students' achievement of Basic Science?

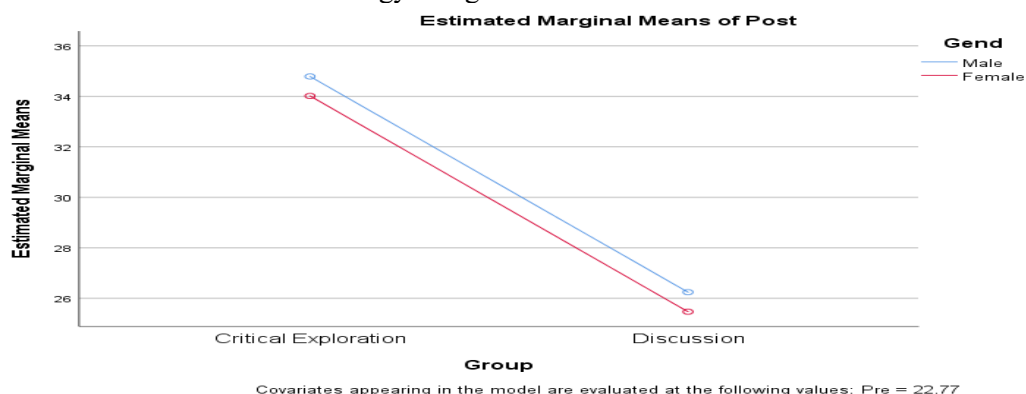


Figure 1: Interaction Effect of Strategy and Gender on Students' Achievement in Basic Science

Figure 1 illustrates that the lines representing male and female students do not intersect, indicating no interaction effect between instructional strategy and

gender on students' achievement in Basic Science. This suggests that the influence of instructional strategies on achievement is consistent across genders.

Hypothesis Three

Table 5: ANCOVA Result for Interaction Effect of Strategy and Gender on Students' Achievement of Basic Science

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1808.642 ^a	4	452.160	106.863	.000	.861
Intercept	361.936	1	361.936	85.540	.000	.554
Pre-Test	558.307	1	558.307	131.950	.000	.657
Group	1296.088	1	1296.088	306.317	.000	.816
Gender	10.599	1	10.599	2.505	.118	.035
Group * Gender	2.903E-5	1	2.903E-5	.000	.998	.001
Error	291.953	69	4.231			
Total	67506.000	74				
Corrected Total	2100.595	73				

Table 5 reveals that $F_{4,69} = 0.000$; $P = 0.998 > 0.05$ which signifies that the observed difference is not significant. Hence, the null hypothesis is not rejected. This means that there is no significant interaction effect of strategy and gender on students' achievement of Basic Science. The R squared value of 0.001 for techniques and gender implies that 0.1% of the difference in the students' achievement scores can be accounted for by strategy and gender. This indicates a very low effect size.

Discussion of Findings

This study has revealed significant difference in the mean achievement scores of students taught Basic Science using critical exploration strategy and those taught using the lecture method in favour of critical exploration strategy. This outcome may be attributed to the fact that the critical exploration strategy offers students opportunities for hands-on activities, collaborative learning, and the exploration of diverse perspectives. These elements foster deeper understanding, enhance problem-solving skills, and promote critical thinking, ultimately enabling students to apply their knowledge to real-life situations, thereby improving achievement in Basic Science. This finding tallies with that of Olagunju and Animasahun (2016) that critical exploration teaching strategies significantly enhanced students' academic achievement in Basic science compared to conventional method. It also agrees with that of Ajayi, Achor and Otor (2020) found that students engaged in learning using innovative instructional strategy outperformed their counterparts taught using lecture method. This finding however does not agree with that of Omega and Kpiranyam (2024) which reported that no statistical significant difference

in achievement of students taught wave motion using 7Es learning model and those taught using PBL strategy.

Findings revealed no significant difference in the mean achievement scores of male and female students taught Basic Science using critical exploration strategy. Furthermore, no significant interaction effect of strategy and gender on students' achievement of Basic Science was recorded. The possible reason is that the critical exploration strategy provided an inclusive learning environment that supported all students similarly, regardless of gender. This finding agrees with that of Ajayi, Achor and Otor (2020) found no significant interaction effect between strategies and gender on students' performance. Also, Buendia and Villanueva (2020) found no significant difference based on gender in performance of learners after the infusion of critical thinking. Similarly, Omega and Kpiranyam (2024) reported no significant difference between the mean academic achievement scores of male and female students taught wave motion using the 7Es learning model. This implies that there is no need for separation of instructional strategies for male and female students as critical exploration can be used successfully to scale up achievement of both groups of students.

Conclusion

The findings of this study provide strong evidence that the critical exploration strategy is more effective than the lecture method in improving students' achievement in Basic Science. Additionally, the absence of a significant difference in achievement between male and female students, as well as the lack of a significant interaction effect between gender and teaching strategy, indicates that critical exploration is an inclusive and

effective approach for all learners. These outcomes highlight the potential of the critical exploration strategy as a gender-responsive instructional strategy.

Recommendations

In light of the study's findings, the following recommendations were made:

1. Basic Science teachers should adopt the use of critical exploration strategy to enhance their instructional practices and improve students' academic achievement in Basic Science.
2. Curriculum developers should incorporate critical exploration strategy into the Basic Science curriculum to develop male and female students' reasoning, creativity and promote a deeper understanding of Basic Science concepts with improved academic performance.
3. STAN and Faculties of Educations of Universities should organize conferences for researchers' discussion on critical exploration to promote its adoption in teaching and learning of Basic Science concepts.

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