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Improving Creativity through Inquiry-Based Learning: Evidence from STEM Secondary School Students in Kaduna State, Nigeria

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Abstract

Creativity is a key twenty-first-century competency and a valued STEM education outcome, yet instruction in many Nigerian secondary schools remains teacher-centred, limiting students' opportunities to develop creative thinking. This study investigated the effect of Inquiry-Based Learning (IBL) on the creativity of Senior Secondary II STEM students in Kaduna State, Nigeria, and examined whether the effect varied by gender. We adopted a quasi-experimental, pretest–posttest, nonequivalent experimental and control group design involving 180 students (96 males, 84 females) selected through multistage sampling from four public secondary schools. Data were collected using an adapted Scientific Creativity Test (reliability = 0.84). The experimental group received a six-week IBL intervention; the control group received conventional teacher-centred instruction. Data were analysed using descriptive statistic and Analysis of Covariance (ANCOVA) at $\alpha = .05$. Students exposed to IBL achieved significantly higher creativity scores than those in the control group, $F(1, 177) = 86.46$, $p < .001$, partial $\eta^2 = .328$, but gender had no significant influence, $F(1, 176) = 0.21$, $p = .648$, partial $\eta^2 = .001$. We conclude that IBL effectively enhances creativity among secondary STEM students irrespective of gender and recommend integrating inquiry-based pedagogy into STEM classroom practice and teacher professional development.

Keywords: inquiry-based learning, scientific creativity, STEM education, secondary school students, constructivism

1 Introduction

Rapid advancement in science and technology has increased the demand for learners who possess creativity, critical thinking, collaboration and problem-solving skills. Consequently, STEM (Science, Technology, Engineering and Mathematics) education has become a major focus of educational reforms worldwide because it equips learners with the competencies needed for innovation and sustainable development (Organisation for Economic Co-operation and Development [OECD], 2023; UNESCO, 2023). Among these competencies, creativity is widely recognised as an essential outcome of effective STEM education, enabling learners to generate original ideas and develop innovative solutions to real-world problems (Khalil et al., 2023). Inquiry-Based Learning (IBL) has emerged as one of the most effective learner-centred instructional approaches for promoting higher-order thinking and meaningful learning in STEM education. Rooted in constructivist learning theory, IBL engages students in questioning, investigation, experimentation, evidence gathering and collaborative problem-solving, while teachers facilitate rather than direct learning (Antonio & Prudente, 2024; Arifin et al., 2025). Through these learning experiences, students actively construct knowledge, develop scientific reasoning and strengthen their creative thinking skills.

Creativity is increasingly viewed as a competency that can be developed through appropriate instructional experiences rather than as an innate ability. Inquiry-Based Learning provides opportunities for students to investigate authentic problems, generate multiple solutions, evaluate evidence and communicate ideas, thereby promoting originality, flexibility, fluency and elaboration, which are key dimensions of creativity (Chen & Chen, 2021; Khalil et al., 2023). Recent studies have shown that inquiry-oriented learning environments significantly improve students' creativity and engagement in STEM subjects (Djaman et al., 2026; Marianingsih, 2025). Despite growing evidence supporting the effectiveness of Inquiry-Based Learning, important research gaps remain. Many previous studies have focused on students' academic achievement, conceptual understanding, motivation and critical thinking, with relatively few investigating creativity as the primary learning outcome (Almulla, 2023; Long et al., 2022). In addition, findings regarding gender differences in inquiry-based learning remain inconsistent. While some studies report that male and female students benefit equally from inquiry-

oriented instruction, others have found significant gender-related differences in learning outcomes (Cheng et al., 2021; Ganajová et al., 2025). Furthermore, most available evidence has been generated in Europe, North America and Asia, with relatively limited quasi-experimental research conducted in sub-Saharan Africa.

In Nigeria, improving STEM education is essential for promoting scientific innovation and national development. However, classroom instruction in many secondary schools remains predominantly teacher-centred, providing limited opportunities for students to engage in inquiry, creativity and collaborative learning (Zakariya & Umahaba, 2025). Although Nigerian researchers have examined the effectiveness of innovative teaching strategies, relatively few studies have investigated the influence of Inquiry-Based Learning on students' creativity, particularly within STEM classrooms. Evidence on whether the approach benefits male and female students equally is also limited. Kaduna State provides an appropriate setting for investigating these challenges given the increasing emphasis on STEM education in secondary schools. However, empirical evidence on the effectiveness of Inquiry-Based Learning in enhancing students' creativity within this context remains scarce. Addressing this gap provides useful evidence for teachers, curriculum developers and policymakers seeking to improve STEM instruction. We therefore investigated the effect of Inquiry-Based learning on the creativity of secondary school STEM students in Kaduna State, Nigeria. Specifically, we examined how Inquiry-Based Learning enhances students' creativity compared with the conventional teaching method, as well as the influence of gender on students' creativity following exposure to inquiry-based instruction. We raised the following research questions: (1) what effect does Inquiry-Based Learning have on the creativity of secondary school STEM students in Kaduna State? (2) What influence does gender have on the creativity of secondary school STEM students exposed to Inquiry-Based Learning in Kaduna State? Answers to these questions are significant for informing STEM instructional practice, teacher professional development and curriculum policy in Nigeria and similar contexts.

2 Literature Review/Theoretical Framework

This study is anchored on Constructivist Learning Theory, as advanced by Piaget (1952) and Vygotsky (1978). The theory views learning as an active process in which learners construct knowledge through interaction with their environment rather than passively receiving information from teachers. It emphasises learner engagement, exploration, reflection and collaboration as essential processes for meaningful learning. These principles form the foundation of Inquiry-Based Learning (IBL), where students actively investigate problems, generate explanations and construct knowledge through evidence-based inquiry. Piaget's cognitive constructivism explains that learning occurs through the processes of assimilation and accommodation, whereby learners modify their existing cognitive structures in response to new experiences. In STEM education, this process encourages students to question assumptions, explore ideas and develop creative solutions to problems. Vygotsky's social constructivism complements this perspective by emphasising that learning is enhanced through social interaction, collaboration and instructional support within the Zone of Proximal Development (ZPD). Through collaborative inquiry and classroom dialogue, students develop higher-order thinking skills and refine their understanding.

Constructivist Learning Theory provides a suitable framework for this study because Inquiry-Based Learning is grounded in its principles. Inquiry activities engage students in questioning, investigation, collaboration, reflection and problem-solving, thereby promoting creativity through the development of originality, fluency, flexibility and elaboration. The theory also supports the view that both male and female students can benefit equally from learner-centred instructional environments that encourage active participation and collaborative knowledge construction. Accordingly, Constructivist Learning Theory provides the conceptual basis for explaining how Inquiry-Based Learning enhances creativity among STEM students and guides the interpretation of our findings on the instructional strategy's effect and gender influence.

2.1 Inquiry-Based Learning as Constructivist Pedagogy

Inquiry-Based Learning (IBL) is a learner-centred instructional approach rooted in Constructivist Learning Theory. It is based on the principle that learners actively construct knowledge through investigation, exploration, collaboration and reflection rather than passively receiving information from teachers (Moemeke et al., 2025; Twizeyimana et al., 2024). In IBL, students formulate questions, investigate real-world problems, analyse evidence and communicate their findings, while teachers serve as facilitators who guide the learning process (Morris, 2025). This approach promotes meaningful learning by actively engaging students in knowledge construction (Singh, 2025). A key feature of IBL is its emphasis on authentic inquiry. Learning begins with meaningful questions or practical problems that encourage students to investigate, evaluate evidence, and develop evidence-based explanations (Krajcik & Czerniak, 2025). Through this process, learners

strengthen conceptual understanding, scientific reasoning, critical thinking and problem-solving skills that are essential for STEM education (Funa, 2026; Kotsis, 2025). Unlike conventional teacher-centred instruction, IBL encourages learner autonomy, collaboration, and reflective thinking within authentic learning contexts (Al-Thani & Ahmad, 2025).

The inquiry process generally follows a sequence of questioning, investigation, evidence collection, analysis, explanation, reflection and communication (Wale & Bishaw, 2020). Although these stages are flexible and iterative, they collectively encourage learners to refine their understanding and apply knowledge to real-life situations. Teachers provide guidance and instructional scaffolding, while students assume responsibility for investigating problems and constructing solutions (Gillies, 2023). One of the major educational benefits of IBL is the development of creativity. By engaging students in open-ended investigations, collaborative problem-solving and the generation of multiple solutions, IBL promotes originality, fluency, flexibility and elaboration, which are key dimensions of creativity (Fikri et al., 2026; Marianingsih, 2025). Previous studies have consistently reported that inquiry-based STEM instruction improves students' creative thinking through active participation and authentic learning experiences (Babalola & Keku, 2024; Chen & Chen, 2021; Khalil et al., 2023; Kim et al., 2023). Accordingly, Inquiry-Based Learning provides the pedagogical foundation for our study because it operationalises the principles of constructivism and offers an effective approach for enhancing creativity among STEM students while providing equal opportunities for both male and female learners to participate actively in the learning process.

2.2 Creativity in STEM Education

Creativity is widely recognised as a key competency for the twenty-first century and an important outcome of STEM education. Beyond its traditional association with the arts, creativity is now considered essential for scientific inquiry, technological innovation, engineering design and mathematical problem-solving. As societies face increasingly complex challenges, there is growing demand for individuals who can generate original ideas, solve problems creatively and apply knowledge in new contexts (OECD, 2023; UNESCO, 2023). Consequently, promoting creativity has become a major objective of STEM education (Kwon & Lee, 2025). Creativity is commonly defined as the ability to produce ideas or solutions that are both original and useful within a particular context (Dow, 2022; Sawyer & Henriksen, 2024). In education, creativity is regarded as a skill that can be developed through appropriate learning experiences rather than an innate ability possessed by only a few individuals. This perspective is consistent with constructivist learning theory, which emphasises active learning, collaboration, exploration and reflection as essential processes for developing creative thinking (Vijayakumar Bharathi & Pande, 2025; Zajda, 2021).

Within STEM education, creativity is demonstrated through learners' ability to formulate questions, generate hypotheses, design investigations, develop multiple solution strategies, and apply knowledge to solve authentic problems. Researchers commonly assess creativity using four dimensions: originality, which refers to generating unique ideas; fluency, the ability to produce many relevant ideas; flexibility, the ability to consider different perspectives or approaches; and elaboration, the ability to expand and refine ideas into meaningful solutions (Kartal et al., 2026; Torrance, 1974). These dimensions provide the framework for assessing students' creative thinking in educational research. Empirical studies consistently show that learner-centred instructional approaches, particularly Inquiry-Based Learning, promote creativity by engaging students in questioning, investigation, collaboration and authentic problem-solving activities (Al-Thani & Ahmad, 2025; Danlami et al., 2025; Ogunjobi et al., 2025). Such learning environments encourage students to develop original ideas, think critically, and apply knowledge creatively. These findings suggest that creativity can be intentionally nurtured through well-designed instructional practices rather than being viewed as a fixed personal characteristic. Accordingly, creativity is regarded as an essential outcome of STEM education, and identifying effective instructional approaches for its development remains a major priority. Inquiry-Based Learning provides one such approach by creating meaningful opportunities for students to investigate problems, construct knowledge and develop creative thinking skills, making it particularly relevant to our study.

2.3 Inquiry-Based Learning and Creativity

Inquiry-Based Learning (IBL) has been widely recognised as an effective instructional approach for promoting creativity in STEM education. Unlike conventional teacher-centred methods that emphasise memorisation and knowledge transmission, IBL actively engages students in questioning, investigation, experimentation, evidence analysis and problem-solving. Through these activities, learners develop original ideas, evaluate alternative solutions and construct knowledge collaboratively, thereby creating favourable conditions for creative thinking (Adeoye & Jimoh, 2023; Li & Tu, 2024). One of the major ways IBL enhances creativity is by promoting divergent thinking, which involves generating multiple and

original solutions to problems. Inquiry-oriented classrooms encourage students to formulate questions, investigate scientific phenomena, analyse evidence and justify their conclusions rather than rely on predetermined answers. These learning experiences foster originality, flexibility and independent thinking. For example, Panjaitan and Siagian (2020) reported that inquiry-based science instruction significantly improved students' scientific creativity, while Marianingsih (2025) found that inquiry learning enhanced learners' originality, fluency and flexibility through active participation and collaborative discussion. Inquiry-Based Learning also promotes creativity by engaging students in authentic STEM investigations. Students identify real-world problems, design investigations, interpret findings and develop evidence-based solutions, enabling them to integrate scientific knowledge with creative thinking. Studies by Singh (2024) and Hebebci and Usta (2022) demonstrated that STEM inquiry activities significantly improved students' creative thinking by encouraging collaboration, innovation and interdisciplinary problem-solving.

Evidence from systematic reviews further supports the effectiveness of IBL in enhancing creativity. Singh (2025) concluded that learner-centred instructional approaches consistently improve higher-order thinking skills, including creativity, through active learning and authentic problem-solving. Similarly, Marianingsih (2025) reported that inquiry-oriented instruction positively influences originality, fluency, flexibility and elaboration. However, these reviews also indicated that the effectiveness of IBL depends on factors such as instructional quality and implementation. Although international studies provide substantial evidence on the positive effect of IBL on creativity, research from sub-Saharan Africa, particularly Nigeria, remains limited. Most Nigerian studies have focused on academic achievement and problem-solving, with relatively little attention given to creativity or possible gender differences in inquiry-based classrooms. Our study therefore addressed this gap by examining the effect of Inquiry-Based Learning on the creativity of STEM students in Kaduna State, Nigeria.

3 Materials and Methods

3.1 Research Design

We adopted a quasi-experimental, pretest–posttest, nonequivalent experimental and control group design. The design was considered appropriate because it allows the evaluation of an instructional intervention under normal classroom conditions where random assignment of individual students is not feasible. Consequently, we assigned intact classes to either the experimental or control group. The experimental group received instruction using the Inquiry-Based Learning approach, while the control group was taught the same STEM content using the conventional teacher-centred method. Both groups completed a creativity pretest before the intervention and a posttest after the six-week instructional period. Pretest scores were used as covariates during data analysis to control for initial differences between the groups.

3.2 Population, Sample and Sampling Technique

The population for the study comprised 2,864 Senior Secondary II (SS II) STEM students enrolled in public secondary schools offering STEM programmes in Kaduna State, Nigeria, during the 2025/2026 academic session. We selected SS II students because they possessed the foundational knowledge required for inquiry-based learning and were not yet preparing for external examinations. A multistage sampling procedure was used to select the sample. First, four public secondary schools offering STEM programmes were purposively selected based on the availability of qualified STEM teachers, adequate instructional facilities and administrative approval. Second, eight intact SS II STEM classes (two from each school) were selected. Finally, the intact classes were randomly assigned to either the experimental or control group through simple balloting. The sample consisted of 180 students (96 males and 84 females). The experimental group comprised 90 students who received instruction using the Inquiry-Based Learning (IBL) approach, while the control group consisted of 90 students taught using the conventional teacher-centred method. The use of intact classes minimised treatment contamination and maintained the normal classroom structure throughout the study.

3.3 Data Collection

We collected data using an adapted Scientific Creativity Test (SCT) developed by Siew and Lee (2017), based on the Scientific Creativity Structure Model of Hu and Adey (2002). The instrument was selected because it measures scientific creativity within STEM contexts. It was adapted to suit Senior Secondary II STEM students in Nigeria and the content of the Inquiry-Based Learning (IBL) intervention. The adapted SCT consisted of four open-ended tasks designed to assess

students' ability to generate ideas, explain scientific phenomena, redesign scientific products and solve authentic STEM problems. These tasks measured the four dimensions of creativity: originality, fluency, flexibility and elaboration. Students completed the instrument during both the pretest and posttest. Responses were scored using an analytic rubric adapted from the Torrance Tests of Creative Thinking (TTCT) (Torrance, 1974), the Scientific Creativity Structure Model (Hu & Adey, 2002) and the scoring guide of Siew and Lee (2017). Fluency was assessed by the number of relevant ideas generated, flexibility by the variety of response categories, originality by the uniqueness of responses and elaboration by the extent to which ideas were developed. Scores for the four dimensions were combined to obtain an overall creativity score, with higher scores indicating higher levels of scientific creativity. The adapted instrument was aligned with the study objectives, the Nigerian secondary school STEM curriculum and the inquiry-based learning activities used during the intervention.

We subjected the adapted Scientific Creativity Test (SCT) to face and content validation by three experts in STEM Education, Educational Psychology and Measurement and Evaluation. The experts evaluated the instrument for clarity, relevance, content coverage and alignment with the dimensions of scientific creativity. We incorporated suggestions made to improve the wording and suitability of test items. We conducted a pilot test involving 30 SS II STEM students from a public secondary school outside the selected sample to establish instrument reliability and analysed the data obtained using Cronbach's alpha. The SCT yielded an overall reliability coefficient of 0.84, indicating good internal consistency. Reliability coefficients for the creativity dimensions were 0.81 (originality), 0.79 (fluency), 0.83 (flexibility) and 0.80 (elaboration). These values exceeded the minimum acceptable reliability coefficient of 0.70 recommended for educational research (Nunnally & Bernstein, 1994). The pilot test helped identify and revise ambiguous items before the main study.

The intervention consisted of a six-week Inquiry-Based Learning (IBL) programme that we developed in line with Constructivist Learning Theory and the Nigerian Senior Secondary School STEM curriculum. The programme comprised two 80-minute lessons per week, giving a total of 12 instructional sessions. Lessons followed the inquiry cycle of questioning, investigation, evidence collection, analysis, explanation, reflection and communication of findings. Students in the experimental group participated in collaborative inquiry activities while the teachers served as facilitators. In contrast, the control group received instruction on the same STEM content using the conventional teacher-centred approach. To ensure treatment fidelity, four experienced STEM teachers, one from each participating school, were trained as research assistants before the intervention, while we conducted regular classroom observations and supervisory visits using a treatment fidelity checklist to ensure consistent implementation of the instructional procedures across all participating schools. All procedures were carried out after obtaining approval to conduct the study from relevant educational authorities and the principals of participating schools.

3.4 Data Analysis

Data analysis was performed using IBM SPSS Statistics version 27. We used mean and standard deviation to answer the research questions by describing students' creativity scores before and after the intervention. We tested null hypotheses using Analysis of Covariance (ANCOVA), with the pretest scores serving as covariate to control for initial differences between the experimental and control groups. Assumptions of ANCOVA, including normality, homogeneity of variance, linearity, homogeneity of regression slopes and independence of observations, were verified and found to be satisfactory. We tested all hypotheses at the 0.05 level of significance, and partial eta squared (η^2) was reported to determine the magnitude of treatment effect.

4 Results

We presented findings according to the research questions raised and their corresponding null hypotheses as follows.

Research Question 1

What is the effect of Inquiry-Based Learning on creativity of STEM students in Kaduna State?

Table **1**

Pretest and Posttest Mean Creativity Scores of Students in the Experimental and Control Groups

Group	*N*	Pretest $\bar{X}$	Pretest SD	Posttest $\bar{X}$	Posttest SD	Mean Gain
Experimental (IBL)	90	51.82	7.41	74.65	6.58	22.83
Control	90	52.10	7.29	60.84	7.13	8.74

Table 1 shows that the experimental group had a pretest mean score of 51.82 (SD = 7.41) and a posttest mean score of 74.65 (SD = 6.58), resulting in a mean gain of 22.83. The control group obtained a pretest mean score of 52.10 (SD = 7.29) and a posttest mean score of 60.84 (SD = 7.13), with a mean gain of 8.74.

Hypothesis 1

H_{01}: There is no significant effect of Inquiry-Based Learning on creativity of STEM students in Kaduna State**.**

Table 2

Analysis of Covariance of Students' Creativity Scores in Experimental and Control Groups

Source	Type III SS	df	MS	F	p	Partial η^2
Corrected Model	5487.46	2	2743.73	46.92	< .001	.347
Intercept	13294.62	1	13294.62	227.42	< .001	.562
Pretest	418.73	1	418.73	7.17	.008	.039
Treatment	5053.61	1	5053.61	86.46	< .001	.328
Error	10342.57	177	58.43	—	—	—
Total	835472.00	180	—	—	—	—
Corrected Total	15830.03	179	—	—	—	—

Table 2 presents the Analysis of Covariance results of Inquiry-Based Learning on students' creativity after controlling for pretest creativity scores. The results revealed that the covariate (pretest creativity) was statistically significant, $F(1, 177) = 7.17$, $p = .008$, partial $\eta^2 = .039$, indicating that students' initial creativity scores contributed significantly to their posttest scores. After adjusting for pretest differences, there was a statistically significant main effect of treatment on students' creativity, $F(1, 177) = 86.46$, $p < .001$, partial $\eta^2 = .328$. This finding indicates that students taught using IBL performed significantly better in creativity than those taught using the conventional teacher-centred approach. The partial eta squared value of .328 indicates a large effect size, suggesting that approximately 32.8% of the variance in students' posttest creativity scores was attributable to the instructional treatment after controlling for pretest scores. We therefore rejected the null hypothesis stating that IBL has no significant effect on students' creativity.

Research Question 2

What is the effect of Inquiry-Based Learning on creativity of male and female STEM students in Kaduna State?

Table **3**

Mean Creativity Scores of Male and Female Students Exposed to IBL

Gender	*N*	Pretest $\bar{X}$	Posttest $\bar{X}$	Mean Gain
Male	48	51.63	74.91	23.28
Female	42	52.04	74.36	22.32

Table 3 shows that male students recorded a mean gain score of 23.28, while female students recorded a mean gain score of 22.32 following exposure to Inquiry-Based Learning.

Hypothesis 2

H_{02}: There is no significant difference in the creativity of male and female STEM students exposed to Inquiry-Based Learning**.**

Table **4**

Analysis of Covariance of Experimental Group Male and Female Students' Scores

Source	Type III SS	df	MS	F	p	Partial η^2
Corrected Model	5518.24	3	1839.41	31.21	< .001	.347
Pretest	425.81	1	425.81	7.23	.008	.039
Treatment	5036.55	1	5036.55	85.49	< .001	.327
Gender	12.46	1	12.46	0.21	.648	.001
Error	10330.11	176	58.69	—	—	—

Table 4 presents the Analysis of Covariance results examining gender influence on students' creativity after controlling for pretest creativity scores and treatment. Results showed that the covariate (pretest creativity) was statistically significant, $F(1, 176) = 7.23$, $p = .008$, partial $\eta^2 = .039$, indicating that students' initial creativity scores significantly influenced their posttest scores. The main effect of treatment remained statistically significant, $F(1, 176) = 85.49$, $p < .001$, partial $\eta^2 = .327$, confirming the effectiveness of IBL in enhancing students' creativity. However, the influence of gender was not statistically significant, $F(1, 176) = 0.21$, $p = .648$, partial $\eta^2 = .001$. This finding indicates that there was no significant difference in the creativity scores of male and female students following exposure to Inquiry-Based Learning. The small effect size (partial $\eta^2 = .001$) further suggests that gender contributed negligibly to students' creativity after controlling for pretest scores and treatment. Consequently, we did not reject the null hypothesis stating that there is no significant difference in the creativity of male and female STEM students exposed to IBL.

5 Discussion

We found out that students exposed to Inquiry-Based Learning (IBL) achieved significantly higher creativity scores than those taught using the conventional teacher-centred approach. After controlling for pretest creativity scores, the effect of treatment was statistically significant, $F(1, 177) = 86.46$, $p < .001$, partial $\eta^2 = .328$, indicating a large effect of the instructional intervention. This finding suggests that Inquiry-Based Learning effectively enhances students' creativity. The finding supports Constructivist Learning Theory (Piaget, 1952; Vygotsky, 1978), which emphasises that learners develop higher-order thinking through active participation. The finding is consistent with those of Chen and Chen (2021) and Hebebci and Usta (2022), who reported that inquiry-based STEM instruction significantly improves students' creative thinking through active participation and authentic problem-solving. It also agrees with Kim et al. (2023), who found that learner-centred inquiry activities enhance creativity by promoting critical thinking, collaboration and learner autonomy. The present study extends these findings by providing empirical evidence from Nigerian secondary schools, where experimental studies on the effect of Inquiry-Based Learning on creativity remain limited.

We found no statistically significant difference in the creativity scores of male and female students exposed to IBL, as indicated by the ANCOVA results, implying that both male and female students benefited from the instructional approach. This indicates that IBL provides equal opportunities for students to participate in inquiry irrespective of gender. The finding supports Constructivist Learning Theory and also agrees with the findings of Chen and Chen (2021) and Kim et al. (2023), who reported that inquiry-based learning promotes creative thinking among male and female students. Findings therefore suggest that Inquiry-Based Learning is an inclusive instructional approach that can be adopted to enhance creativity among STEM students irrespective of gender.

6 Limitations

This study has some limitations that should be acknowledged. First, the use of intact classes rather than individual random assignment of students may have introduced pre-existing group differences that could not be fully controlled by the pretest covariate adjustment. Second, the study was conducted in four public secondary schools within a single state (Kaduna State), which limits the generalisability of the findings to other contexts. Third, the six-week duration of the IBL intervention may not fully capture the longer-term effects of the approach on students' creativity. Finally, creativity was

assessed using a single instrument, the Scientific Creativity Test, which, although valid and reliable, may not capture all dimensions of students' creative thinking. These limitations should be considered when interpreting and generalising the findings of this study.

7 Directions for Future Research

Future studies should consider employing longer intervention periods to examine the sustained effect of Inquiry-Based Learning on students' creativity. Multi-state or multi-region replications involving a more diverse sample of schools would strengthen the generalisability of findings. In addition, future researchers may adopt a mixed-methods approach that incorporates qualitative exploration of students' inquiry processes, alongside multiple creativity assessment instruments, to gain deeper insight into how Inquiry-Based Learning fosters creative thinking among STEM students.

8 Conclusion

Our findings revealed that students taught using Inquiry-Based Learning achieved higher creativity scores than those taught using the conventional teacher-centred approach. We also found no significant gender influence on students' creativity, indicating that IBL is an inclusive and effective instructional approach for developing creativity among STEM students. These findings highlight the potential of Inquiry-Based Learning for improving STEM education in Kaduna State and, by extension, similar contexts in Nigeria. We therefore recommend that teachers should be trained and retrained on how to integrate IBL into STEM classroom practice to enhance students' creativity and other higher-order thinking skills. Curriculum developers and policymakers should also consider embedding inquiry-based pedagogy into STEM teacher-education programmes and classroom practice guidelines.

9 Declarations

Ethical Statements: This study involved secondary school students, the majority of whom were minors. Approval to conduct the study was obtained from relevant educational authorities in Kaduna State and the principals of the participating schools prior to data collection. Written informed consent was obtained from the parents/guardians of the participating students, and assent was obtained directly from the students themselves before their participation. Participants and their parents/guardians were informed of the purpose of the study, the voluntary nature of participation, and their right to withdraw at any stage without penalty. Confidentiality of participants' identities and responses was maintained throughout the study.

Conflict of Interest: The authors declare neither financial nor non-financial conflict of interest.

Author Contributions: Aliyu Suleiman Aliyu conceptualised the study, designed and implemented the Inquiry-Based Learning intervention, collected the data and drafted the manuscript. Safiya Shafiu Muhammed contributed to the study design, supervised the data analysis, critically reviewed and revised the manuscript for important intellectual content. Both authors read and approved the final manuscript and agree to be accountable for its content.

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