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Ethno-STEM Integrated Project-Based Learning to Improve Students' Creative Thinking Skills

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Abstract

This study investigates the impact of integrating Ethno-STEM with project-based learning (PjBL) on enhancing creative thinking skills among secondary school students in Nigeria. Acknowledging the critical role of creativity in STEM education, the research addresses the gap between traditional teaching methods and the need for innovative approaches that foster creative thinking. Traditional STEM education, often characterized by rote memorization, has been criticized for not adequately preparing students to tackle real-world problems innovatively. The incorporation of Ethno-STEM into PjBL represents an avant-garde pedagogical strategy, aimed at bridging cultural knowledge with scientific inquiry, thereby making learning more relevant, engaging, and effective in developing creative problem-solvers. This quasi-experimental study, conducted over four months, involved 84 students divided equally into an experimental group, which experienced the Ethno-STEM integrated PjBL, and a control group, which continued with conventional curriculum. Creative thinking skills were assessed through pretests and posttests, focusing on fluency, flexibility, and originality. The results demonstrated a significant improvement in the creative thinking abilities of the experimental group compared to the control group, indicating that the Ethno-STEM integrated PjBL approach effectively enhances students' creative thinking skills. These findings underscore the potential of integrating cultural knowledge and project-based learning in STEM education to nurture innovation and creative problem-solving capabilities among students.

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INTRODUCTION

The landscape of STEM education has historically been dominated by traditional teaching methods that emphasize rote memorization and standardized testing, often neglecting the cultivation of creative thinking and problem-solving skills. This conventional approach has inadvertently stifled students' ability to think innovatively, a crucial skill for

advancing innovation and development in science, technology, engineering, and mathematics (STEM) fields (Freeman et al., 2014). Encouraging creative thinking not only fosters innovation but also empowers students to tackle challenges from diverse perspectives, leading to the generation of effective and original solutions. As a researcher in the field of STEM education on the African continent, we have observed a critical challenge that underpins the educational landscape: the low creative thinking skills among STEM students. This issue is multifaceted, with one of the primary causes being the prevalence of inauthentic learning experiences that do not connect students with their cultural and environmental contexts, particularly the rich ethnoscience traditions of Africa. This disconnection has profound implications for how students engage with and understand STEM subjects, ultimately affecting their ability to think creatively and innovatively. A recent investigation conducted by Mutsvangwa and Zezekwa (2021) underscores the challenges Africa faces in offering and implementing high-quality STEM education.

In recent years, there has been a growing recognition of the need to reform STEM education to better align with the demands of the modern world. This includes addressing issues such as poorly developed curricula, inadequate teaching methods, and a lack of hands-on training, all of which hinder students' acquisition of STEM skills (Birzina et al., 2021). Studies have highlighted the importance of active learning methods in STEM education, where students engage in activities that require them to actively process and apply information, such as problem-solving exercises and collaborative discussions, leading to improved learning outcomes (Wieman, 2014). Additionally, the integration of online teaching and learning in STEM education has become increasingly important, especially in response to challenges like the COVID-19 pandemic, highlighting the need for innovative approaches to teaching and learning in STEM disciplines (Mnguni & Mokiwa, 2020).

Moreover, the implementation of integrated PjBL in STEM education has been shown to have a positive impact on students' thinking skills, particularly in subjects like physics and mathematics (Vistara et al., 2022). By incorporating STEM approaches through engineering design processes and PjBL models, educators can enhance students' mathematical creative thinking skills and foster a passion for learning in STEM fields (Vistara et al., 2022). Furthermore, the use of technology and mixed learning environments has been found to enhance collaboration and creative thinking skills among students, emphasizing the importance of technology preparedness in promoting effective learning outcomes in STEM education (Fideli & Aliazas, 2022). Overall, these findings underscore the significance of adopting innovative and interdisciplinary approaches in STEM education to nurture the next generation of creative and critical thinkers in science, technology, engineering, and mathematics (Aini & Narulita, 2020).

To address the deficiency in nurturing creative thinking skills within STEM education, a shift towards methodologies that promote creativity, curiosity, and innovation is crucial (Stains et al., 2018). Ethnoscience and project-based learning (PjBL) emerge as promising educational paradigms that, when integrated, have the potential to significantly enhance

students' creative thinking abilities in STEM fields (Stains et al., 2018). Ethnoscience, with its focus on diverse cultural perspectives of the natural world, provides a rich source of knowledge that can inspire students to think more broadly and creatively (Stains et al., 2018). By incorporating ethnoscience into STEM education, students are exposed to alternative problem-solving methods, encouraging them to consider unconventional solutions and approaches (Stains et al., 2018).

PjBL complements this by offering a pedagogical framework that inherently fosters creative thinking (Bathgate et al., 2019). PjBL emphasizes learning through real-world challenges, requiring students to engage in complex projects that demand a creative approach to problem-solving (Bathgate et al., 2019). Through PjBL, students actively explore and navigate uncertainties, often leading to innovative solutions drawing upon their expanded perspectives from ethnoscience (Bathgate et al., 2019). This hands-on, inquiry-based approach ensures that learning is personalized and relevant, essential for developing creative thinking skills (Bathgate et al., 2019).

Integrating an ethnoscience perspective within a PjBL framework not only enriches the educational experience but also grounds STEM education in cultural relevance and authenticity (Sabat et al., 2020). Students are challenged to consider not only the technical aspects of their solutions but also the cultural, ethical, and societal implications, fostering a holistic approach to problem-solving (Sabat et al., 2020). This multifaceted strategy encourages students to apply creative thinking not just in technical solutions but also in culturally informed ways, preparing them to be empathetic, innovative, and globally conscious contributors to the STEM fields (Sabat et al., 2020).

The fusion of PjBL with an ethnoscience perspective presents a potent solution to the creativity crisis in STEM education in Africa. By creating an educational environment that values diversity, embraces complexity, and encourages exploration and innovation, students' creative thinking skills can be significantly enhanced, benefiting both individual learners and the broader STEM community with diverse perspectives and innovative solutions to global challenges. Through a structured investigation, this study is designed to methodically examine the effect of incorporating Ethnoscience into project-based learning (PjBL) within STEM education in Africa, specifically aiming to enhance students' abilities in creative thinking. Consequently, the research inquiries are outlined as follows.

- How does integrating Ethnoscience with project-based learning (PjBL) in STEM education influence the enhancement of students' creative thinking skills?

Novelty of the Current Study

The novelty of the current study lies in its innovative approach to integrating Ethnoscience within a project-based learning (PjBL) framework to enhance creative thinking skills in STEM education in Africa. Unlike traditional methods that often prioritize rote learning and standardized testing, this research endeavors to bridge the gap between cultural knowledge and scientific inquiry, fostering a learning environment that not only encourages

creativity and problem-solving but also imbues a deep respect and understanding for diverse cultural perspectives on science and technology. By combining Ethnoscience, which emphasizes the rich, varied ways different cultures understand and interact with the natural world, with the dynamic, hands-on approach of PjBL, this study aims to create a more engaging, relevant, and deeply educational experience for students. This integration promises to expand students' cognitive frameworks, encouraging them to think more broadly and creatively, and to approach problems from novel, culturally-informed perspectives. Such an approach is groundbreaking in its attempt to prepare students not only with the technical skills required in STEM fields but also with a global mindset and innovative problem-solving capabilities that consider cultural contexts and ethical implications.

Furthermore, this research contributes to the field of STEM education in Africa by addressing the urgent need for pedagogical strategies that cultivate creative thinking, a critical skill in the innovation-driven modern world. The study's focus on the synergy between Ethnoscience and PjBL represents a significant departure from conventional educational models, aiming to harness the power of cultural diversity and interdisciplinary learning to foster a new generation of creative, critical thinkers. By evaluating the impact of this integrated approach on students' creative thinking abilities, the study offers valuable insights into how STEM education can be reformed to better meet the challenges of the 21st century. This novel methodology not only has the potential to enhance students' engagement and learning outcomes but also to inspire a broader educational movement towards more inclusive, innovative, and effective teaching practices in STEM disciplines. The implications of this research extend beyond the classroom, offering a model for how educators worldwide can incorporate cultural knowledge and creative pedagogies to nurture the critical and creative capacities needed to address global scientific and technological challenges.

Ethnoscience-STEM Studies in Africa

In the realm of Ethno-STEM education, there is a growing interest in integrating indigenous knowledge systems with modern scientific and technological education, particularly focusing on African cultures. One notable area of exploration is ethnobotany within African communities, where traditional knowledge of plant species and conservation methods provides valuable insights into biology and environmental science (Berkes et al., 2000). Educational projects in East Africa have successfully connected students with elders possessing extensive knowledge of medicinal plants, fostering an appreciation for traditional ecological knowledge and biodiversity conservation (Mahomoodally, 2013). By immersing students in local cultural contexts, these initiatives bridge the gap between theoretical STEM knowledge and practical applications, offering a holistic understanding of the subjects.

Astronomy is another significant area where ethnoscience has been integrated into STEM education in Africa, drawing on indigenous African societies' historical astronomical observations (Alexiades et al., 2021). Projects in South Africa have demonstrated how incorporating indigenous astronomical practices into the curriculum enriches students' understanding of astronomy while fostering pride in cultural heritage. This integration not

only enhances students' scientific knowledge but also nurtures a sense of connection to their cultural roots, showcasing the value of ethnoscience in providing culturally relevant and engaging learning experiences (Alexiades et al., 2021; Ndaipa et al., 2023). Moreover, in engineering and technology education, initiatives across Africa are utilizing local materials and traditional techniques to teach engineering principles in a culturally contextualized manner (Aikenhead & Ogawa, 2007). Programs in West Africa, for instance, focus on traditional architectural techniques to help students grasp engineering concepts through indigenous methods, promoting sustainability and innovation rooted in local practices. These approaches not only enhance technical knowledge but also encourage students to develop solutions grounded in local wisdom, highlighting the potential of ethnoscience to enrich STEM education in Africa (Aikenhead & Ogawa, 2007).

Ethno-STEM education in Africa is shaping a generation of learners who are not only academically proficient but also culturally grounded and globally competent, ready to tackle 21st-century challenges with a blend of traditional wisdom and scientific innovation. By integrating indigenous knowledge systems into STEM education, these initiatives are fostering a deep understanding of science and technology while promoting respect for diverse cultural practices and traditions.

METHODS

Research Design

The study adopted a quasi-experimental design with a quantitative approach to investigate the impact of Ethno-STEM integrated project-based learning on students' creative thinking skills. In line with the objectives of the research, this design facilitated the comparison between an experimental group, which experienced the Ethno-STEM integrated project-based learning, and a control group, which underwent traditional teaching methods. This comparison was made possible through the administration of pretests and posttests to both groups, thereby assessing the effect of the Ethno-STEM integrated project-based learning over a period of four months. The choice of a quasi-experimental design was instrumental in isolating the effect of the intervention, providing a structured and controlled environment to evaluate the impact of innovative teaching methodologies on creative thinking skills within the STEM education context.

The experimental group was exposed to a curriculum that incorporated Ethno-STEM principles with project-based learning, aiming to engage students deeply with the material by linking it to their cultural and environmental context. This approach was hypothesized to foster a higher degree of creative thinking compared to the control group, which continued with the conventional curriculum. The duration of the intervention was carefully chosen to allow significant engagement with the project-based activities, ensuring that any observed differences in creative thinking skills could be attributed to the pedagogical approach. Pretest and posttest scores from both groups were then analyzed to measure the effectiveness of the Ethno-STEM integrated project-based learning in enhancing students' creative thinking capabilities.

Participants

The study involved 84 secondary school students from Nigeria, equally divided into an experimental group and a control group, each comprising 42 students. The participants, aged between 15 and 16 years, were selected through a purposive sampling technique to ensure a homogenous age group, thus minimizing age-related variability in creative thinking skills. This age range was chosen based on the premise that students within this bracket are at a critical stage in developing higher-order thinking skills, making them ideal candidates for the study. Ethical considerations were paramount, with the research adhering to ethical standards concerning human participation. Informed consent was obtained from all participants, ensuring that they were fully aware of the study's nature and their role in it, thereby upholding the principles of voluntary participation, confidentiality, and the right to withdraw at any time.

The demographic selection of participants from a single secondary school in Nigeria provided a unique insight into the influence of Ethno-STEM integrated project-based learning within a specific educational and cultural context. This setting allowed for a controlled comparison between the two groups, ensuring that any observed differences in creative thinking skills could be attributed to the educational intervention rather than extraneous variables. The balanced distribution of participants between the experimental and control groups further bolstered the study's validity by minimizing potential biases that could affect the outcomes.

Research Procedures

The research unfolded in several distinct phases, starting with the preparation phase, where objectives were defined, instruments were developed, and participants were selected. Following this, the four-month intervention phase commenced, during which the experimental group engaged with Ethno-STEM integrated project-based learning, while the control group received traditional instruction. This phase was crucial for implementing the educational intervention and observing its effects on the participants.

Data collection occurred before and after the intervention, employing pretests and posttests to gauge the creative thinking skills of both groups. This approach ensured a comparative analysis of the impact of Ethno-STEM integrated project-based learning. After data collection, the analysis phase involved both descriptive and statistical techniques to evaluate the effectiveness of the intervention. Finally, the research reporting phase concluded the study, presenting findings, discussing implications, and suggesting directions for future research. This structured approach ensured a comprehensive evaluation of the Ethno-STEM integrated project-based learning's impact on enhancing students' creative thinking skills.

Instruments

The primary instrument for collecting data on students' creative thinking skills was an essay test, specifically designed to assess fluency, flexibility, and originality. Fluency refers to the ability to generate numerous ideas or solutions to a given problem, indicating the breadth

of a student's creative thinking. Flexibility involves the ability to produce diverse categories of ideas, reflecting the adaptability of the student's thought processes. Originality, on the other hand, measures the uniqueness of the ideas generated, showcasing the student's capacity for innovative thinking. The essay test was meticulously developed to ensure it aligns with these indicators, providing a comprehensive measure of creative thinking skills.

The validation of the instrument was a critical step, ensuring its reliability and validity as a tool for measuring creative thinking skills. Psychometric properties were thoroughly examined, with the instrument undergoing a rigorous validation process that involved expert review and pilot testing. This process confirmed the test's capability to accurately and reliably assess the dimensions of creative thinking it was designed to measure. Consequently, the instrument's validity and reliability endorsement made it a suitable tool for data collection, enabling the research to capture nuanced insights into the participants' creative thinking skills.

Analysis

Data collected from the pretest and posttest were subjected to both descriptive and statistical analyses. The descriptive analysis focused on calculating the average scores of students' creative thinking before and after the intervention, along with the computation of effect sizes to measure the magnitude of the intervention's impact. This analysis provided an immediate, understandable depiction of the changes in creative thinking skills among the participants.

Statistical analysis was conducted using the ANOVA test, chosen for its ability to compare means across more than two groups. This was particularly relevant in assessing the differences in creative thinking skills between the experimental and control groups, both before and after the intervention. The use of ANOVA facilitated the determination of whether the Ethno-STEM integrated project-based learning had a statistically significant effect on enhancing students' creative thinking skills. The significance level was set at 0.05, ensuring that findings were rigorously tested for statistical significance, thereby confirming the reliability of the results in indicating the effectiveness of the pedagogical intervention.

RESULTS AND DISCUSSION

In the discussion of the impacts of integrating Ethnoscience with Project-Based Learning (PjBL) on students' creative thinking skills within STEM education, Table 1 presents a critical analysis comparing the creative thinking abilities of students in both experimental and control groups before and after the intervention. This quantitative overview encapsulates the essence of the study's findings, shedding light on the effectiveness of an innovative teaching approach that blends cultural insights with scientific inquiry. The data reveal how this pedagogical strategy influences students' ability to think creatively, a key component in fostering innovation and problem-solving skills in STEM fields. Through a detailed examination of mean scores, standard deviations, and the range of scores, Table 1 lays the groundwork for a deeper discussion on the significance of ethno-STEM integrated PjBL in enhancing creative

thinking among students, setting the stage for a comprehensive analysis of the educational intervention's outcomes.

Table 1. Results of descriptive analysis of students' creative thinking skills

Variable	Experimental group		Control group	
	Pretest	Posttest	Pretest	Posttest
Valid	42	42	42	42
Mean	5.220	6.675	5.434	5.759
Std. Deviation	1.414	1.661	1.465	1.438
Minimum	2.560	3.710	1.570	2.730
Maximum	8.280	9.640	7.850	8.840

The data presented in Table 1 from the study on Ethno-STEM integrated project-based learning and its impact on students' creative thinking skills illustrates the outcome of the experimental and control groups before and after the intervention. For the experimental group, which was exposed to Ethno-STEM integrated project-based learning, there's a noticeable increase in the mean score of students' creative thinking skills, moving from 5.220 in the pretest to 6.675 in the posttest. This indicates a significant improvement in the creative thinking abilities of students who participated in the project-based learning that integrated ethnoscience. Additionally, the standard deviation in the posttest scores of the experimental group increased from 1.414 to 1.661, suggesting a wider spread of the scores around the mean, which could indicate varying degrees of improvement among the students. The minimum and maximum scores in the experimental group also rose, from 2.560 and 8.280 in the pretest to 3.710 and 9.640 in the posttest, respectively, further evidencing the positive impact of the Ethno-STEM integrated project-based learning approach on enhancing creative thinking skills.

In contrast, the control group, which continued with traditional teaching methods, showed a marginal increase in the mean score of creative thinking skills, from 5.434 in the pretest to 5.759 in the posttest. The relatively static standard deviation values (from 1.465 to 1.438) and the slight increase in minimum and maximum scores (from 1.570 and 7.850 in the pretest to 2.730 and 8.840 in the posttest, respectively) suggest that the traditional teaching methods had a much less pronounced effect on students' creative thinking abilities. The comparative analysis between the experimental and control groups underscores the effectiveness of the Ethno-STEM integrated project-based learning in fostering creative thinking among students. This approach not only promotes a deeper engagement with the material by connecting it to their cultural and environmental context but also encourages the exploration of innovative solutions, as reflected in the significant improvements in the experimental group's scores compared to the control group's marginal gains. Complementing the results in Table 1, Figure 1 and Figure 2 shows the distribution plots of students' creative thinking skills scores.

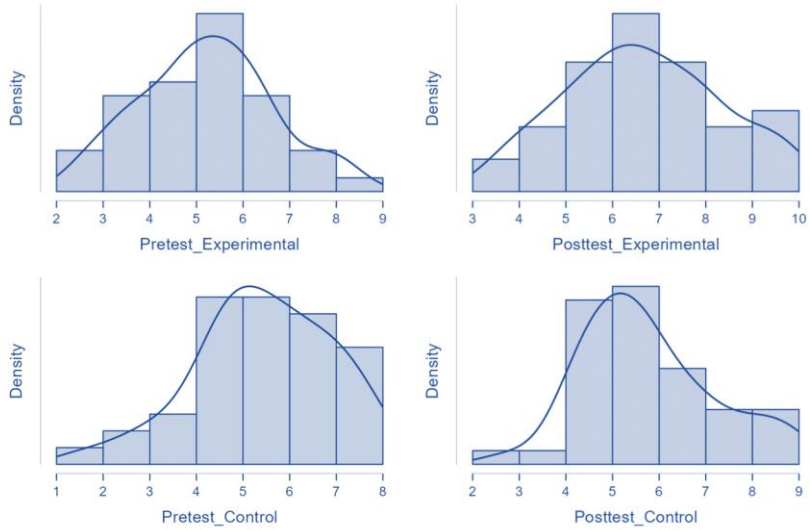

Figure 1. The distribution plots of students' creative thinking skills scores.

Figure 1 presents the distribution plots of students' creative thinking skills scores across the experimental and control groups, both before and after the Ethno-STEM integrated project-based learning intervention. The pretest and posttest distributions for the experimental group indicate a rightward shift in scores, illustrating an increase in creative thinking abilities post-intervention. This shift is evidenced by higher density in the upper score range in the posttest, suggesting that the Ethno-STEM integrated PjBL approach effectively improved creative thinking skills. In comparison, the control group's plots show a more subtle change, with a slight rightward shift from pretest to posttest, implying only a modest improvement in creative thinking skills. This visual contrast between the two groups' score distributions highlights the impact of the culturally-relevant, hands-on learning strategies employed with the experimental group, affirming the potential benefits of such educational innovations in STEM fields.

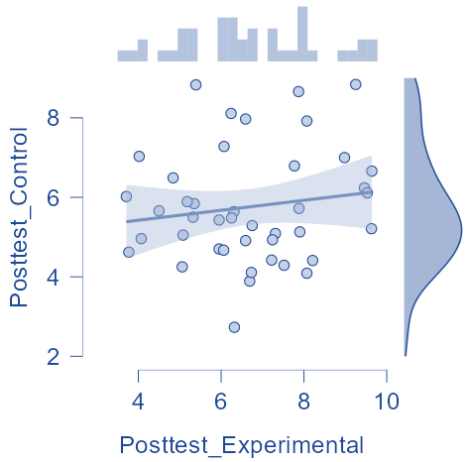

Figure 2. Scatter plots of students' creative thinking skills scores.

Figure 2 depicts a scatter plot comparing the posttest creative thinking skills scores of the experimental group against those of the control group, with a fitted line indicating the overall trend between them. The data points are dispersed in a way that suggests a positive correlation: as scores in the experimental group increase, so do scores in the control group, but to a lesser extent. This is visually reinforced by the density plots on the margins, showing a more pronounced improvement in scores for the experimental group as compared to the control group. The shaded area around the trend line may represent a confidence interval, providing a visual sense of the reliability of the predictive relationship between the two sets of scores.

The comparative increase in the experimental group's scores post-intervention underscores the potential efficacy of the Ethno-STEM integrated project-based learning in enhancing creative thinking. Furthermore, the results of the ANOVA test followed by post hoc tests are presented in Table 2, Table 3 and Table 4.

Table 2. The results of the ANOVA test within subject effects

Case	Sum of Squares	df	Mean Square	F	p	η^2_G
RM Factor	33.250	1	33.250	70.796	< .001	0.083
RM Factor * Group	13.419	1	13.419	28.571	< .001	0.035
Residuals	38.512	82	0.470			

Note. Type III Sum of Squares, RM = repeated measures (pretest vs. posttest)

Table 3. The results of post hoc tests – RM Factor

RM Factor	Mean Difference	SE	t	p_{holm}
Pretest - posttest	-0.890	0.106	-8.414	< .001

Table 4. The results of post hoc tests – Group * RM Factor

Group * RM Factor		Mean Difference	SE	t	p_{holm}
Control, Pretest	Experimental, Pretest	0.214	0.327	0.656	0.514
	Control, Posttest	-0.325	0.150	-2.170	0.099
	Experimental, Posttest	-1.241	0.327	-3.796	0.001
Experimental, Pretest	Control, Posttest	-0.539	0.327	-1.648	0.205
	Experimental, Posttest	-1.455	0.150	-9.729	< .001
Control, Posttest	Experimental, Posttest	-0.916	0.327	-2.803	0.024

The study's findings, encapsulated in Tables 2, 3, and 4, offer a nuanced insight into the effects of integrating Ethnoscience with Project-Based Learning (PjBL) on enhancing students' creative thinking skills within the context of STEM education. The results from the ANOVA test, presented in Table 2, reveal significant within-subject effects for both the repeated measures (RM) factor, which compares pretest and posttest scores, and the interaction between the RM factor and the group variable. The significant F-values for the RM factor ($F=70.796$, $p<.001$, $\eta^2G=0.083$) and the interaction between the RM factor and group ($F=28.571$, $p<.001$, $\eta^2G=0.035$) indicate that the Ethno-STEM integrated PjBL had a substantial impact on

students' creative thinking abilities, with a notable difference between the experimental and control groups' performance over time. These findings underscore the effectiveness of the pedagogical intervention in fostering enhanced creative thinking skills.

Delving deeper, the results of the post hoc tests for the RM factor, as outlined in Table 3, highlight a mean difference of -0.890 (SE=0.106, t=-8.414, p<.001) between the pretest and posttest scores, emphasizing a significant improvement in creative thinking skills post-intervention. This improvement is attributed to the experimental group's exposure to the Ethno-STEM integrated PjBL approach. The negative mean difference indicates that posttest scores were higher than pretest scores, evidencing the positive impact of the intervention on enhancing students' creative capacities. Further examination through the post hoc tests for the Group * RM Factor interaction (Table 4) elucidates the differential impact of the intervention across groups. Specifically, the most notable mean difference observed is between the experimental group's posttest and pretest scores (-1.455, SE=0.150, t=-9.729, p<.001), showcasing a significant leap in creative thinking skills for the experimental group compared to the control. Conversely, the control group showed lesser degrees of improvement, as indicated by the smaller mean differences. The interaction effects reveal how the Ethno-STEM integrated PjBL not only significantly improves creative thinking skills but also does so more effectively than traditional teaching methods. These results collectively affirm the value of incorporating Ethnoscience and PjBL into STEM education as a means to significantly elevate students' creative thinking abilities, thereby contributing to more innovative problem-solving and learning outcomes in STEM fields.

The integration of Ethnoscience with Project-Based Learning (PjBL) within STEM education presents a pioneering approach to fostering creative thinking skills among students. This method contrasts sharply with traditional teaching paradigms that have dominated the educational landscape, as highlighted in the introduction of this study. By drawing on the findings from Mutsvangwa and Zezekwa (2021), the current research builds upon the understanding that African STEM education faces challenges in nurturing creativity due to a disconnection from the continent's rich ethnoscience traditions. This discussion aims to contextualize the current study's results within the broader academic discourse, illustrating how this innovative pedagogical strategy not only enhances students' creative thinking skills but also bridges a crucial gap in STEM education.

The significant improvement in creative thinking skills observed in the experimental group, as shown by the data in Table 1, demonstrates the effectiveness of integrating Ethnoscience with PjBL. This finding is consistent with previous studies, such as those by Vistara et al. (2022), which underscore the positive impact of integrated PjBL on students' thinking skills. However, the current study extends these findings by incorporating an ethnoscience perspective, thereby offering a more culturally relevant and engaging approach to STEM education. The increase in mean scores from pretest to posttest in the experimental group signifies not only a quantitative improvement in creative thinking but also suggests a qualitative shift in how students engage with STEM subjects, reflecting deeper, more

innovative thought processes. Furthermore, the marginal gains observed in the control group underscore the limitations of traditional teaching methods in fostering creative thinking, echoing the concerns raised by Freeman et al. (2014) about the stifling effect of conventional approaches on innovation. The stark contrast in outcomes between the experimental and control groups reinforces the argument for a pedagogical shift towards methods that emphasize active, contextual learning over rote memorization.

The ANOVA test results presented in Tables 2, 3, and 4 further substantiate the effectiveness of the Ethno-STEM integrated PjBL in improving creative thinking skills. The significant within-subject effects and the interaction between the RM factor and group validate the hypothesis that the intervention would have a notable impact on students' creative capacities. These statistical findings align with the research objectives, confirming the superiority of the Ethno-STEM integrated PjBL approach over traditional teaching methods in promoting creative thinking. The literature review by Aguilera and Revilla (2021) emphasizes the importance of creativity in STEM education and highlights the significance of integrating arts (STEAM) to enhance student creativity. This aligns with the findings of the current study, which showcases the positive impact of Ethno-STEM integrated PjBL on creative capacities. Additionally, the study by Sutaphan & Yuenyong (2023) underscores the role of PjBL in enhancing students' creative thinking skills, further supporting the notion that the Ethno-STEM integrated approach can effectively cultivate innovation and creativity among learners.Moreover, the research by Wardani et al. (2021) sheds light on the scientific literacy skills developed through STEM-integrated PjBL models, indicating a holistic approach to education that not only enhances creativity but also scientific understanding.

In light of the preceding studies and the current research findings, it is evident that the integration of Ethnoscience with PjBL offers a viable solution to the challenges faced in STEM education, particularly in fostering creative thinking skills. This study not only contributes to the academic discourse on STEM education reform but also provides practical insights for educators looking to cultivate innovation and creativity among students. By bridging cultural knowledge with scientific inquiry, the Ethno-STEM integrated PjBL approach enriches STEM education, making it more relevant, engaging, and effective in developing the creative problem-solvers needed to tackle the challenges of the 21st century.

CONCLUSION

The study successfully demonstrates the effectiveness of integrating Ethno-STEM with project-based learning (PjBL) in enhancing students' creative thinking skills within STEM education. By incorporating ethnoscience, the approach not only enriched the learning experience with cultural relevance but also promoted innovative problem-solving skills. This is evidenced by the significant improvements in the experimental group's creative thinking abilities. This integration effectively bridges the gap between cultural knowledge and scientific inquiry, offering a more engaging, relevant, and deeply educational experience for students. The findings suggest that by connecting STEM subjects with the students' cultural and environmental context, their ability to think creatively and innovate is significantly

enhanced, thereby addressing the critical challenge of nurturing innovative talents in STEM fields in Africa.

LIMITATION

The research was conducted within a specific cultural and educational context in Nigeria, which may limit the generalizability of the results to other regions or educational systems. Furthermore, the study's quasi-experimental design, while effective in isolating the intervention's impact, might not fully account for all external variables that could influence students' creative thinking skills. Additionally, the reliance on pretest and posttest scores as the primary means of assessment may not capture the full breadth of creative thinking development over time.

RECOMMENDATION

Based on the study's findings, several recommendations are proposed for educators and policymakers. Firstly, there is a need to further explore and implement Ethno-STEM integrated PjBL approaches across different cultural contexts and educational systems, to validate and expand upon these results. Moreover, educators should consider incorporating ethnoscience and PjBL into the curriculum to actively foster creativity and innovation among students. Finally, future research should aim to overcome the current study's limitations by employing longitudinal designs and including diverse educational settings. This would provide a more comprehensive understanding of the impact of Ethno-STEM integrated PjBL on creative thinking skills and help to cultivate a new generation of creative, critical thinkers in the STEM fields.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

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Conflict of interests

The authors declare no conflict of interest.

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