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Zamfara International Journal of Science Technology Education and Mathematics (ZIJTEM) is the official Journal of the Department of Science Education, Faculty of Education Federal University Gusau Zamfara State, Nigeria. The Journal publishes articles of diverse fields of interest in Sciences, Technology, Education and Mathematics. Papers reporting original research and extended version of already established conference and journal articles are welcomed. Papers for publication are selected through peer review process to ensure originality, relevance and readability. ZIJSTEM is published quarterly which spans throughout the year i.e. March, June, September and December, respectively.

The aim and scope of the journal is to provide an academic medium and an important reference for the advancement and dissemination of information that supports high level learning, teaching and research in the fields of Sciences, Technology, Education and Mathematics.

The articles in this volume are academic and professional discourse written by reputable scholars in their area of specialization.

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FORWARD

On Behalf of the staff and students of the Department of Science Education, Federal University Gusau, Zamfara state, Nigeria, we humbly acknowledge and thank Allah (S.W.T) the most beneficent, the most merciful for without his will, collection and computation of this journal publication would not have been possible. May all praise be ascribed unto Him. The department is sincerely grateful to its accommodating mentor Prof. Tukur Adamu, Vice Chancellor, Federal University, Gusau and his management team for giving the department enabling environment for academic activities. The department's profound gratitude goes to Prof. Umar Sodangi who doubled as the Dean, Faculty of Education, Federal University, Gusau and Associate Editor of Zamfara International Journal of Science, Technology, Education and Mathematics (ZIJSTEM). Furthermore, Special gratitude goes to our contract and visiting Professors, the staff and students of the Department of Science Education, Federal University, Gusau, for their supports and foresight towards actualizing the dream of the department.

The Zamfara International Journal of Science, Technology, Education and Mathematics (ZIJSTEM) is a brain child of Department of Science Education with the aim of bringing science and technology education into global and well recognized journals of science and technology education research. This is first of its kind, among Science Education Departmental Journals in Northwest, Nigeria and by extension one of the highly placed departmental journals in Nigeria, considering its online visibility and originality, based on well-known global best practices.

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The Zamfara International Journal of Science, Technology, Education and Mathematics (ZIJSTEM) calls for scholarly articles for review and possible publication in its next edition (Volume 3, Number 4, December, 2026), ZIJSTEM publishes articles that emphasizes on research development and application within the field of Sciences, Technology, Education and Mathematics. All manuscripts are reviewed by editorial review committee. Contributions must be original, not previously or simultaneously published elsewhere, and are critically reviewed before they are published. Papers, which must be written in English language, should have good grammar and proper terminologies.

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Leveraging on Artificial Intelligence Technology in Boosting Cassava Production in Nigeria: The Gains and Constraints

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Abstract

Artificial Intelligence (AI) technology is reshaping agricultural landscape globally by employing data-driven, efficient, and scalable production methods. Nigeria, as the world's largest producer of cassava, faces persistent challenges like low yield per hectare, pest infestations, climate variability, and inefficient farming techniques. This study focuses on the potential of AI technology to exploit and enhance the nation's agricultural potentials and productivity. The study decisively examines the application of AI in cassava production in Nigeria, focusing on its gains and constraints. It adopted ways to addressing the critical challenges like climate variability, scarce access to digital farming techniques, and the need for sustainable practices. Using a descriptive and analytical approach based on secondary data from FAO, NBS, IITA, and recent scholarly publications, the study explores AI-driven technologies such as precision agriculture, machine learning, remote sensing, and automation. Findings from the study reveal that AI technology application in cassava production can significantly improve productivity, optimize resource utilization, and reduce post-harvest losses. However, adoption can be constrained by high costs, poor infrastructure, low digital literacy, and weak policy frameworks. This paper investigates how AI technology can be employed to achieve the mass production of cassava in Nigeria, while critically examining the associated gains or benefits and constraints.

Keywords: Artificial Intelligence (AI) technology, Cassava production, Boosting production, Gains, Constraints

Introduction

The integration of Artificial Intelligence (AI) technology in boosting agricultural products is the embedding of the technology capabilities into its processes, tools, and infrastructure to achieving efficiency, innovation, and sustainability in the agriculture sector. The study clearly examines the integration of Artificial Intelligence (AI) technology in the production of cassava in Nigeria. From available records, Nigeria produces over 60 million metric tons of cassava annually claimed the National Bureau of Statistics (NBS, 2024), still its productivity is not at its optimal state. The study evaluates the AI technology applications like precision agriculture, machine learning-based disease detection, and predictive analytics. In the submission of (Adah et al, 2024), applied technologies in the boosting of cassava production include; improved varieties, approved planting times, ideal spacing, appropriate herbicide application, and mechanization. By World Bank report (2023), agriculture remains a cornerstone of Nigeria's economy, contributing approximately 20–25% to the Gross Domestic Product (GDP) and employing over 35% of the country's labor force. However, the agricultural sector in Nigeria faces multifaceted challenges that impact the nation's food security and economic stability, caused by climate variability, irregular rainfall and unexpected weather extremes, which poses a real threat to boosting crop yields, leading to financial losses for farmers, claimed Food and Agricultural Organization (FAO, 2020). Cassava also called manihot esculenta, is a main staple and industrial crop in Nigeria, among other crops cultivated in the country. Cassava holds an undeniable place in the economy of the nation due to its role in food security, industrial applications, and export potential. Despite the nation's global leadership in cassava production, Nigeria faces low yield per hectare unlike countries such as Thailand and Brazil who are also cassava producing countries. Nigeria produces over 60 million metric tons of cassava annually, accounting for about 20% of global production according to (NBS, 2024). Despite this seemly impressive output,

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productivity per hectare remains relatively low compared to countries such as Thailand and Brazil as mentioned earlier. This discrepancy is largely attributed to traditional farming techniques or methods, limited mechanization, pest infestations, and scarce access to modern agricultural technologies such as AI in the production of cassava in the country. Chikoti et al (2022), attributed the low yield of cassava to factors including lack of quality varieties, poor soils, limited access to capital, competition for labor, pests and diseases. However, the emergence of AI technology has opened the door of opportunities to bridge the gap through data-driven farming techniques.

Artificial intelligence (AI), defined as the ability of machines to perform tasks that typically require human intelligence, has emerged as a transformative force in modern agriculture. Cassner et al (2019) as cited by Aamo et al (2021), agreed that agriculture in Africa is predicted to take the continent out of poverty if technology is properly utilized for mechanized farming. AI technologies such as machine learning, computer vision, and predictive analytics offer opportunities to optimize agricultural processes, improve yield, and enhance decision-making as in cassava production. From the result of a research carried out by Lasisi and Olufemi (2024), they claimed that the application of AI technologies in farming led to a 40% reduction in food waste with huge efficiency improvements. They also observed a 30% degree in processing time and a 25% reduction in transportation costs compared with the production without the application of AI technologies.

AI Technologies in Agriculture

1. Machine learning; is used for predictive analysis, yield forecasting, and disease detection.
2. Computer vision; enables image-based disease identification and crop monitoring.
3. Internet of Things (IoTs); use sensors to collect real-time data on soil moisture, temperature, and crop health.
4. Robotics and automation; are used to automate planting, irrigation, and harvesting processes.
5. Remote sensing; is used as satellite and drone imagery to provide large-scale farm monitoring.
6. Precision agriculture; this is an AI enabled site-specific farming practices, improving soil and crop management.
7. Disease detection; is an AI-powered image recognition systems that detect cassava diseases early.
8. Yield prediction; these predictive models analyze weather and soil data to forecast output of cassava.
9. Smart irrigation; are automated systems that optimize water usage in the production of cassava.
10. Supply chain optimization; is the use of AI to improve logistics, reducing post-harvest losses.

Cassava the tropical crop

Cassava is a tropical crop that is consumed by over 800 million people globally. The crop is essential as a staple food for most livelihoods in Nigeria. Cassava's main advantages are; it is drought resistant, resilient in poor soils and can be processed into local and international products like garri, fufu, tapioca, flour, ethanol, animal feed and HQCF claimed (Kayode, 2025). And that the production of cassava by the manual method in the country has been poor as a result of diseases like cassava mosaic and brown streak, and limited access to market, agro processors, lack of extension support and the idea technology. The above challenges have brought about limit in the massive production of cassava in the nation, resulting in constraints that create reduced income for farmers and results in after-harvest losses. To ameliorate these constraints required strategic solution hence the urgency to employing AI technology in boosting the production of cassava in Nigeria. Equally, to improve productivity, disease detection, wider market access, and extension support services for sustainable and profitable cassava farming for the Nigerian cassava farmers, will make cassava farming

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appealing to the Nigerian youths in the states identified with cassava farming and encourage their active involvement for job security and reduction in jobs unemployment.

Statement of the Problem

Regardless of being the largest producer of cassava globally, Nigeria faces significant crisis in cassava production. The main issues involved are: Low yield per hectare; High post-harvest losses; Poor pests and diseases management; Limited use of mechanization vis-à-vis technology, and; The effects of inconsistent climate. These palpable observed challenges act as hindrances to the country's ability to fully develop the economic and food security potential as regards cassava production. However, the integration of AI technology presents a potential solution and a way out of the above issues, but its adoption remains a challenge and limited.

Objectives of the Study

The study aims to:

1. Examine the role of AI technology in boosting cassava production in Nigeria,
2. Identify the gains of AI technology adoption in the Nigerian agricultural sector,
3. Analyze the constraints associated with AI technology adoption and application in boosting cassava production in Nigeria,
4. Provide recommendations for the effective integration of AI technology in cassava production.

Theoretical Framework

The framework for the study is based on the technology acceptance model (TAM). The technology acceptance model explains how farmers adopt to new technologies based on their perceived usefulness and the ease of their application. In the rural areas of Nigeria, farmers' willingness to adopt AI technology in farming depends on the affordability, accessibility, and the seeming benefits. The adoption of AI technology in agriculture is influenced by awareness, social networks, and institutional support called the diffusion of innovations theory. This concerns the degree of spread of innovations within a society. AI technology integration in agriculture requires precise coordination across several systems that include; policy frameworks, production, processing, and logistics, known as the theory of systems.

Review of related literature

Key findings reveal that AI technology applications, such as predictive modeling for crop yields, Pest prevention, disease detection, and resource optimization, significantly improve farming efficiency and sustainability. Akis (2016) as cited by (Aamo et al, 2021) sees smart farming as the application of modern information and communication technologies (ICTs) skills into agriculture in order to achieve higher productivity. The research highlights the importance of tailored AI solutions that consider local agro-ecological conditions and farmer capacities. Furthermore, it identifies barriers to AI technology adoption, including data availability and cultural variability, which may hinder the widespread implementation of these technologies. The implications of this study underscore the necessity for comprehensive training programs and supportive policy frameworks to facilitate the integration of AI technology in agriculture will ultimately contribute to food security and economic stability in Nigeria. Yakubu et al (2024), highlighted the importance of tailored AI solutions that consider local agro-ecological conditions and farmers capabilities and proceeded to identify barriers to AI adoption like data unavailability and cultural variability. This research not only provides actionable recommendations for stakeholders but also contributes to the broader discourse on sustainable agricultural practices in Nigeria. The agricultural industry in Nigeria faces multifaceted challenges that impact the nation's food security and economic stability. Climate variability, marked by irregular rainfall and unexpected weather extremes, poses a significant threat to crop yields,

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leading to financial losses for farmers (FAO, 2020). Limited access to modern farming techniques exacerbates these challenges, particularly for small-scale farmers in rural areas who lack advanced machineries and efficient irrigation systems. The limited access disparity hampers productivity, perpetuating a cycle of low agricultural output and constrained economic growth opined (Ajibefun and Adejumo, 2018). Recent researches underscore the transformative potential of advanced technologies, especially artificial intelligence (AI) technology, in mitigating the identified challenges confronting agriculture in the country. AI applications such as predictive modeling for crop yields and disease detection enable farmers such as those of cassava farming to make data-driven decisions, improving efficiency and productivity claimed (Kamilaris et al., 2018). According to (Shuaibu et al., 2024), decision tree repressors, show promising results in crop yield prediction, with accuracy rates as much as 72%. While Precision agriculture techniques such as drones and remote sensing enhance productivity by optimizing resource use and enable targeted interventions, declared (Omoseni et al., 2022). Moreover, studies on renewable energy integration, such as wind turbine modeling, offer potential solutions to Nigeria's energy challenges, indirectly supporting agricultural productivity, affirmed (Babawurun et al., 2023). However, the adoption of these technologies remains limited due to the socio-economic barriers existing in the nation. Many studies focus on technical advancements, often neglecting the unique challenges faced by small-scale farmers, such as limited access to technology, training, and financial resources, confirmed (Benos et al., 2021). FAO (2023) reports that AI-driven agriculture can increase productivity by up to 25%. International Institute of Tropical Agriculture (IITA) (2022), highlights the role of digital tools in combating cassava diseases such as cassava mosaic virus. Similarly, studies show that predictive analytics improves planting decisions and yield outcomes. Global studies highlight the transformative impact of AI technology in agriculture. According to (FAO, 2023), AI-driven technologies can increase crop yields by up to 25% while reducing the input costs. The outcome of research carried out by the International Institute of Tropical Agriculture (IITA, 2022) shows that digital tools can effectively combat cassava diseases such as cassava mosaic virus and cassava brown streak disease. (Legg et al, 2024), claimed that diseases such as the cassava mosaic disease (CMD), and the cassava brown streak disease (CBSD) are the main biotic treats to cassava production in Africa. According to (UNDP, 2023) report, AI technology adoption remains relatively low due to infrastructural and economic constraints in Africa. However, pilot projects in countries like Kenya and Ghana demonstrated promising outcomes in precision farming. In the opinion of (Ogboru, 2025), the advancements in digital technologies present opportunities to enhance agricultural production among farmers in the South-West region of Nigeria and the nation in general.

Research Methodology

This study adopts a qualitative and descriptive approach using secondary data from FAO, NBS, and IITA. The content analysis was used to evaluate AI technology applications and implications.

AI Applications in Cassava Production are identified as;

1. Precision farming using drones and satellite imagery.
2. AI-based pest and disease detection systems.
3. Predictive analytics for yield forecasting.
4. Smart irrigation systems powered by the internet of Things (IoTs).

Overview of Cassava value chain in Nigeria

The cassava value chain includes:

1. Production (planting and cultivation)
2. Processing into products such as; garri, tapioca, flour, starch, fufu, etc.

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3. Storage and preservation
4. Distribution and marketing

The above value-chain requires AI technologies application to boosting cassava production in Nigeria. Specifically in the main cassava-producing states that include; Benue, Kogi, Ogun, Ondo, and Delta. However, the inefficiencies across the value chain as lead to significant losses and reduced profitability for farmers in the affected states and Nigeria in general.

AI technology Applications in Cassava Production Trend in Nigeria

Year	Production(Million Tonnes)
2020	59.5
2021	60.0
2022	60.8
2023	61.2
2024	62.0

Source: NBS (2024)

Empirical Analysis (Conceptual Framework)

Artificial Intelligence refers to systems that are capable of performing tasks that typically require human intelligence. In agriculture, AI technology integrates machine learning, computer vision, and IoTs to enhance decision-making.

Hypotheses

H_0: AI technology adoption has no significant effect on cassava production.
H_1: AI technology adoption significantly improves cassava production.
H_0: Infrastructure does not influence AI technology adoption.
H_1: Infrastructure significantly influences AI technology adoption.

Discussion

Secondary data suggests a positive correlation between AI adoption and increased productivity, though moderated by infrastructural factors.

Data Presentation and Analysis

Cassava production in Nigeria with AI technology displayed a steady growth as shown below:

Year	Production (Million Tons)
2020	59.5
2021	60.0
2022	60.8
2023	61.2
2024	62.0

However, yield per hectare remains low, indicating inefficiency rather than lack of production scale.

Table 1: Group Statistics

Groups	N	Mean	Std	standard Error
AI technology users	21	18.5	3.20	0.698
Non-AI techngy users	15	12.3	2.80	0.723

Table 2: Independent Samples Test

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Test Variable	t-value	df	Sig. (2-tailed)	Mean Difference
Cassava Yield	6.17	34	0.000	6.20

There is a statistically significant difference in cassava yield between farmers that use AI technology and the farmers that do not apply AI technology in the production of cassava in Nigeria, $t(34) = 6.17$, $p < 0.05$.

Gains of AI technology in Cassava Production in Nigeria

Some of the gains are;

1. Increased productivity; AI technology enhances yield through optimized farming practices.
2. Resource efficiency; It reduces waste of water, fertilizers, and pesticides.
3. Improved decision-making; Farmers rely on data rather than intuition.
4. Reduced losses; Better storage and logistics systems.
5. Economic growth: Boosts agri-business and export opportunities.

Constraints of AI technology in the cassava production in Nigeria

Some of the constraints are;

1. High cost: AI tools are expensive for small-scale farmers.
2. Poor infrastructure: Limited electricity and internet access.
3. Low digital literacy; Farmers lack technical skills.
4. Policy gaps: Weak government support policy for agric-technology.
5. Data Limitations; Insufficient localized agricultural data.

Discussion of Findings

While AI technology offers noteworthy benefits in all areas of life, its implementation in Nigeria must be contextualized. Unlike developed countries, Nigeria as a nation faces structural challenges that limit scalability. Therefore, a hybrid approach that is; combining traditional knowledge and modern technology is essential to boosting cassava production in the country. Hence, Nigeria as a matter of policy should implement the following;

1. Develop national AI-agriculture policies suitable for the country.
2. Invest massively in rural ICT infrastructure.
3. Provide subsidies for AI tools to boost cassava production in the country.
4. Governments and concerned agencies should strengthen agricultural research institutions across the length and breadth of the nation.

Conclusion

Artificial Intelligence (AI) technology holds a transformative potential for cassava production in Nigeria. Hence, its strategic implementation and policy support by the relevant authorities are essential to maximizing its gains or benefits to the Nigerian cassava farmers and channel for improved financial boost and bumper harvest for the nation's food security. AI technology has the potential to revolutionize cassava production in Nigeria by improving efficiency, productivity, and sustainability. Nevertheless, the success of its involvement in the production of cassava depends on addressing factors such as; the infrastructural, economic, and policy challenges confronting its massive and affordable production. Therefore, a coordinated effort involving the government at all levels, the private sector, and the farmers is essential.

Recommendations

The recommendations are offered for sustainable AI technology adoption to boosting cassava production in Nigeria. Since agriculture is the responsibility of all the tiers of government, they

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should make it a priority to invest in rural ICT infrastructure, subsidize AI technology tools, and ensure to promote agricultural digitization across the length and breadth of the country. Capacity building programs are equally essential to equip farmers with the essential skills to boost production. Hence, the need to:

1. Promote farmer education and digital training for cassava farmers.
2. Encourage public-private partnerships in the production of cassava.
3. Develop localized AI technological solutions for the production of cassava.
4. Improve data collection systems for cassava farmers.

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Influence Of Traditional Institutions on Community-Driven Developmental Projects in Otukpo Local Government Area, Benue State, Nigeria

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Abstract

Traditional institutions have remained vital agents of governance, cultural preservation among others. This study examined the influence of traditional institutions on community development in Otukpo Local Government Area, focusing on their roles in leadership, conflict resolutions, resource mobilization and socio-economic transformation. The study adopted a theoretical and empirical approach using relevant development theories such as structural functionalism, dependency theory. Three research questions were generated, and three hypotheses were formulated and tested at 0.05 level of significance, chi-square statistical tool was used to analyze the hypotheses. The findings revealed that traditional institutions significantly contributed to community development through grassroots mobilization, peace building and local governance, despite challenges such as political marginalization and modernization pressures. The study also revealed that traditional institutions had significant influence on promoting grassroots participation in Otukpo Local Government Area of Benue State. The study recommended that integrating traditional institutions into formal governance structures can enhance sustainable community development. It further recommended that the government should provide clear constitutional roles for traditional institutions to enhance their legitimacy and effectiveness.

Keywords: *Traditional Institutions, Community-Driven Developmental Projects and Otukpo*

Introduction

Traditional institutions in Nigeria are indigenous governance structures rooted in customs and traditions. They are headed by traditional rulers such as chiefs, kings and elders who serve as custodians of culture and mediators in community affairs (Omitola, 2022). Before colonial rule, traditional institutions were central to governance, administration and development. They coordinated communal labour, settled disputes and ensured social order. In Benue State, particularly Otukpo Local Government Area, traditional rulers play significant roles in community leadership and development activities. Community development refers to the collective efforts of people to improve their living conditions through projects such as road constructions, schools, health care facilities and water supply (Ogwudile, 2019). Despite modernization, traditional institutions remain relevant due to their proximity to the people. However, their effectiveness has been challenged by political interference, reduced authority and lack of constitutional roles. Traditional institutions in Nigeria are many at times challenged due to proper conditional roles. In Benue State like the Och'idoma and district heads play significant roles in grassroots administrations and community coordination. Historically, traditional institutions served as the primary machinery for governance, conflict resolution and mobilization of community members for development purposes. Even in contemporary times, they remain vital in rural development due to their closeness to the people and deep understanding of local customs and needs.

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In Otukpo Local Government Area, traditional institutions are believed to influence development initiatives through leadership, mobilization and conflict resolutions. Studies show that traditional resolutions contribute to governance, resource mobilization and cultural preservation, although their effectiveness varies across communities (Olawoyin, 2023). Before the colonial rule, these institutions governed the people effectively through moigenous administrative systems that ensured justice, equity and development. Community development in Otukpo LGA largely depends on collective participation where traditional leaders act as catalyst for development initiatives such as road construction, school building and health programs. However, the influence of these institutions is increasingly challenged by political interference, youth resistance, and limited constitutional recognition.

Objectives of the Study

The broad objective of this study is to determine the influence of traditional institutions on community-driven developmental projects in Otukpo LGA of Benue State. Specifically:

1. Examine the role of traditional institutions in Otukpo Local Government Area of Benue State.
2. Assess the influence of traditional institutions on community-Driven developmental Projects in Otukpo Local Government Area of Benue State.
3. Identify challenges affecting traditional institutions in Otukpo Local Government Area of Benue State.

Research Question

1. What are the roles of traditional institutions in Otukpo Local Government Area of Benue State?
2. What is the influence of traditional institutions on community-Driven developmental Projects in Otukpo Local Government Area of Benue State?
3. What are the challenges affecting traditional institutions in Otukpo Local Government Area of Benue State?

Research Hypotheses

1. Traditional institutions have no significant influence on community-driven developmental Projects in Otukpo LGA of Benue State.
2. Traditional institutions do not significantly contribute to conflict resolutions in Otukpo Local Government Area of Benue State.
3. There is no Significant challenges affecting traditional leadership and grassroot participation in Otukpo LGA of Benue State.

Research Methodology

This chapter presents the methodology adopted for the study on the influence of traditional institutions in community- Driven developmental Projects in Otukpo Local Government Area. It describes the research design, area of study, population sample size and sampling techniques, instruments for data collection, validity and reliability of the instruments, method of data collection and technique for data analysis.

Population of the Study

The population of the study comprises all residents of selected communities in Otukpo Local Government Area of Benue State. This includes, community members, traditional leaders, youth representatives and local government officials. The estimated population is large, therefore a sample is drawn.

Sample Size

A total of 150 respondents is selected for the study. This sample size is considered adequate for statistical analysis and generalization.

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Sampling Technique

The study adopts a simple random sampling technique, ensuring that every member of the population has an equal chance of being selected. In addition, purposive sampling is used to select key informants such as traditional rulers and community leaders due to their relevance to the study.

Method of Data Collection

Data is collected through primary sources using the questionnaire. Copies of the questionnaire are distributed to respondents. Respondents are given adequate time to complete them and the researcher retrieves completed questionnaires.

Method of Data Analysis

Data collected is analyzed using statistical package for social sciences (SPSS). Inferential statistic of chi-square (II^2) is used to test the hypothesis.

Presentation of Results

Demographic Data Analysis

Table 1: Gender categorization

Gender	Frequency	Percentage (%)
Male	85	56.7
Female	65	43.3
Total	**150**	**100**

The table shows that 56.7% of respondents are male, while 43.3% are female. This indicates the male formed majority of the population.

Table 2: Age Distribution

Age group	Frequency	Percentage (%)
18-25	40	26.7
26-35	55	36.7
36 and above	55	36.7
Total	**150**	**100**

From the table, most respondents fall within the 36 years and above, indicating mature participants with relevant knowledge of community development.

Analysis of Research Questions

Research question 1

What are the roles of traditional institutions in Otukpo Local Government Area of Benue State?

Table 3: Response on significant role of traditional institution in Community Development

Response	Frequency	Percentage (%)
Strong agree	65	43.3
Agree	50	33.3
Disagree	20	13.3
Strongly disagree	15	10
Total	**150**	**100**

A total of 76.62 which fall under agree (SA + A) agreed that traditional institutions play significant roles in community development. This confirms their importance in Otukpo Local Government Area of Benue State.

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Research question 2

What is the influence of traditional institutions on community-Driven developmental Projects in Otukpo Local Government Area of Benue State?

Table 4: Response on influence of traditional institution in Community Development

Response	Frequency	Percentage (%)
Strong agree	70	46.7
Agree	45	30
Disagree	20	13.3
Strongly disagree	15	10
Total	**150**	**100**

From the above 76.7% of the respondents agree that traditional institutions significantly influence development in Otukpo LGA of Benue State.

Research question 3

What are the challenges affecting traditional institutions in Otukpo Local Government Area of Benue State?

Table 5: Response on influence of traditional institution in Community Development

Response	Frequency	Percentage (%)
Strong agree	60	40
Agree	55	36.7
Disagree	20	13.3
Strongly disagree	15	10
Total	**150**	**100**

From the table majority of the respondents (76.7%) agree that traditional institution face serious challenges such as political interference and lack of legal backing in Otukpo LGA of Benue State.

Hypotheses testing (chi-square analysis)

Hypothesis one

Ho_1: Traditional institution have significant influence on community-Driven developmental Projects in Otukpo LGA of Benue State.

Table 6: Chi-square analysis

Response	observed (o)	Expected (E)	(O-E) 2/E
SA	70	37.5	28.17
A	40	37.5	1.50
D	20	37.5	8.17
SD	15	37.5	13.50
Total	**150**	**1500**	**51.34**

Decision rule; Critical value (df = 3, a = 0.05) = 7.81; Calculated X^2 = 51.34

Decision, Since 57.34> 7.81, the statement of the null hypotheses one is rejected. The conclusion is that, there is no significant influence of traditional institutions on community-Driven developmental Projects in Otukpo Local Government Area of Benue State.

Hypothesis two

Ho_2: traditional institutions do not significantly influence conflict in Otukpo Local Government Area of Benue State.

Table 7: Chi-square calculation

Response	Observed (O)	Expected (E)	(O-E) 2/E
SA	68	37.5	25.02
A	47	37.5	2.41
D	20	37.5	8.17
SD	15	37.5	13.50

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Total	**150**	**1500**	**49.10**

Decision

49.10> 7.81, hence HO_2, the statement of hypothesis two is rejected. The conclusion is that traditional institution significantly influences conflict resolution in Otukpo Local Government Area of Benue State.

Hypothesis three

HO_3: There is no significant relationship between traditional leadership and grassroot participation in Otukpo LGA of Benue State.

Table 8: Chi-square calculation

Response	Observed (O)	Expected (E)	(O-E) 2/E
SA	65	37.5	20.17
A	50	37.5	4.17
D	20	37.5	8.17
SD	15	37.5	13.50
Total	**150**	**1500**	**46.01**

Decision

46.07 > 7.81, implying that the statement of the null hypothesis 3 is rejected, the conclusion is that there is a significant relationship between traditional institutions and grassroots participation in Otukpo Local Government Area of Benue State.

Discussion of finding

This section discusses the major findings of the study in relation to the research questions, hypothesis, theoretical review and existing empirical literature in influence of traditional institutions on community-Driven developmental Projects in Otukpo Local Government Area of Benue State. The findings of the study revealed that traditional institutions have significant influence on community-Driven developmental Projects in Otukpo. This is evident from the high percentage of respondents over 75% who agreed that traditional leaders play active roles in development initiative from hypothesis one chi-square to confirmed the result on the calculated value exceeded the theoretical position of Takott Parsons (1951). Finding also revealed that traditional institutions play significant role in conflict resolution as evidenced by the high level of agreement among respondents and the rejection of the second null hypothesis. This finding aligns with the heirs of Emile Durkhein (1983), who emphasized that social institutions are necessary for maintaining social order and cohesion. Conflict resolution by traditional rulers helps prevent social instability, thereby creating an enabling environment for development. Findings also revealed that traditional institutions significantly enhance grassroots participations in community development. Statistical test confirmed a significant relationship between traditional institutions and grassroots participations, leading to the rejection of null hypothesis three. The finding supports participatory development theory, which emphasized the importance of involving local people in development processes. Traditional institutions in Otukpo LGA act as facilitators of participation by encouraging communal labour, promoting collective decision making and enhancing project ownership.

Conclusion

This study investigated the influence of traditional institutions on community-Driven developmental Projects. Base on the findings it can be concluded that Traditional institutions influences community-Driven developmental Projects in Otukpo Local Government Area of Benue State, Nigeria

Recommendations

Based on the findings of the study, the following recommendations were made:

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1. Constitutional recognition: The government should provide clear constitutional roles for traditional institutions to enhance their legitimacy and effectiveness.
2. Strengthening Collaboration: The government should strengthen collaboration with traditional institutions while preserving their neutrality and autonomy.
3. Youth engagement: Efforts should be made to involve young people in traditional governance systems to enhance community and relevance.
4. Financial support: Government and development agencies should provide financial assistance to traditional institutions for community development projects.

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Effects of Reggio-Emilia Approach on Engagement and Achievement in Physics-related Concepts among Upper Basic School Students in Ilorin, Kwara State, Nigeria

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Abstract
Students' persistent low engagement and achievement in physics-related concepts have remained a concern in Nigerian basic education. Although learner-centred pedagogies have been widely advocated, empirical evidence on the application of the Reggio Emilia approach in Basic Science and Technology classrooms remains limited. This study investigated the effects of the Reggio Emilia approach on Upper Basic II students' engagement and achievement in physics-related concepts in Ilorin, Kwara State, Nigeria. A quasi-experimental pretest-posttest non-equivalent control group design was employed. A total of 120 students from selected public basic schools in Ilorin participated in the study during the 2025/2026 academic year, comprising 60 students in the experimental group and 60 in the control group. Data were collected using the Physics-related Concept Achievement Test (PCAT) and the Students' Physics-related Concept Engagement Scale (SPCES). Descriptive statistics and Analysis of Covariance (ANCOVA) were used to analyze the data at the 0.05 significance level. The findings revealed that students exposed to the Reggio Emilia approach demonstrated significantly higher achievement ($F(1,117) = 64.17$, $p < .001$, $\eta^2p = .354$) and engagement ($F(1,117) = 48.74$, $p < .001$, $\eta^2p = .294$) than their counterparts taught using the conventional teaching method. Furthermore, no significant gender differences were observed in students' achievement and engagement outcomes. The findings provide empirical support for constructivist and learner-centred instructional practices in science education. It is concluded that the Reggio Emilia approach is an effective strategy for enhancing students' engagement and achievement in physics-related concepts. The study recommends integrating it into Basic Science and Technology instruction and suggests further research into its long-term effectiveness across diverse educational contexts.

Keyword: Reggio Emilia approach, Physics education, Student engagement, Academic achievement, Basic Science and Technology

Introduction
Physics education is important for any nation that wants to grow its scientific and technological capacities. Learners can cultivate knowledge and problem-solving skills, and engage in scientific thinking and creativity. These traits promote the advancement of any nation. Nigerian classrooms begin teaching physics-related concepts in basic education with Basic Science and Technology. This aims to help learners develop basic scientific thinking and curiosity. However, in Nigerian basic

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schools, engagement, understanding of concepts, and the perceived significance of teaching science for STEM education are poor. Teaching and learning science are unsatisfactory. This unsatisfactory state is usually blamed on a lack of teaching and learning resources, teacher-centered instruction, rote learning, little collaborative learning, and almost no inquiry learning (Bass et al., 2024; Jobir & Regassa, 2024; Newman & Gentile, 2020). This poor state of science teaching and learning has led to a demand for innovative learner-centered methods of pedagogy. The focus of such teaching methods is to develop new ways of organizing teaching within the classroom. One pedagogy that has garnered significant interest is the Reggio Emilia approach. It is a constructivist and inquiry-based pedagogy for science teaching that promotes hands-on learning, exploration, collaboration, and creativity. There is considerable empirical support for the necessity and efficacy of learner-centered and constructivist instructional approaches in teaching and learning physics. For instance, Taghvaee et al. (2025) observed better student achievement and the development of improved study habits with the incorporation of active learning compared to traditional teaching practices. Based on the findings, the use of participatory teaching strategies improved students' conceptual understanding and increased their active participation in physics instruction. The same phenomenon was observed when engaging students with collaborative and inquiry-based teaching approaches, which resulted in significantly better achievement than for those not engaged. Additionally, several studies have reported that teaching methods involving some degree of contextualization and collaboration have positively impacted Nigerian physics students' academic performance. Doz and Sliško, (2024) observed an increase in physics students' scores following the use of collaborative learning and reflective practice techniques. In a study conducted in Nigeria, Walker and Warfa (2017) reported positive scores among physics students following the use of a cognitively guided inquiry-based teaching and learning method. In Ilorin, the use of thematic teaching in physics was shown to be more effective than traditional teaching methods in improving student understanding and achievement of physics concepts. These studies show the importance of modern teaching and learning methods for physics education in Nigeria. From the perspective of the Reggio Emilia approach, positive trends have also been observed in the field of science education. Numerous studies (Dessie et al., 2023; Nicholus et al., 2023; Wang et al., 2025) point to the positive results of attentive and constructive teaching, coaching, experiential teaching, example-based active teaching, teaching that underscores the student's active role, and the integration of real-life experiences. This study has also shown that the approach is in harmony with teaching quality indicators such as active teaching, relevant teaching, and reflective teaching practice. Similarly, Sriarun et al. (2025) stated that the Reggio Emilia teaching method is more effective than the traditional teaching method in improving the academic achievement of students. The Reggio Emilia approach is very relevant to teaching and learning in modern science because of the importance of expressing imagination and ideas, social interaction, and the focus on the learner as an active participant who constructs knowledge.

Statement of the Research Problem

Despite growing support for learner-centred teaching, instruction in many Nigerian basic schools remains predominantly teacher-centred, with students often acting as passive recipients of knowledge. This approach limits students' active participation, conceptual understanding, and interest in science, resulting in poor engagement and achievement. Although previous studies have examined instructional strategies such as flipped classrooms, guided inquiry, and peer tutoring in physics education, there is limited empirical evidence on the use of the Reggio Emilia approach in Nigerian basic schools, particularly in Ilorin. Furthermore, many studies have focused mainly on students' achievement while paying less attention to student engagement, which is essential for

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meaningful learning. This gap necessitates investigating whether the Reggio Emilia approach can improve both students' engagement and achievement in Basic Science and Technology. Therefore, this study examines the effects of the Reggio Emilia approach on Upper Basic II students in selected public basic schools in Ilorin, Kwara State.

Objectives of the study

1. To determine the effect of the Reggio Emilia approach on students' classroom engagement in physics concepts.
2. To examine the effect of the Reggio Emilia approach on students' achievement in physics concepts.
3. To compare the classroom engagement of students taught physics concepts using the Reggio Emilia approach and those taught using the conventional teaching method.
4. To compare the achievement of students taught physics concepts using the Reggio Emilia approach and those taught using the conventional teaching method.

Research Questions

1. To what degree does the Reggio Emilia approach enhance classroom engagement?
2. To what degree does the Reggio Emilia approach enhance the achievement of physics-related concepts among learners in Ilorin, Nigeria?

Hypotheses

1. There will be no significant difference in the engagement of learners taught physics-related concepts using the Reggio Emilia approach compared to those taught through the traditional approach in Ilorin.
2. There will be no significant difference in the achievement of physics concepts among learners taught using the Reggio Emilia approach compared to those taught through the traditional approach in Ilorin.
3. There will be no significant interaction between treatment and gender on the engagement with the concepts of physics in Nigerian basic schools in Ilorin.
4. There will not be a significant interaction between treatment and gender on the achievement of the concepts of physics in Nigerian basic schools in Ilorin.

Research Methodology

This study utilized a pretest-posttest non-equivalent control group design, a type of quasi-experimental design. It was the most suitable design because participants were grouped into intact classes, situated in a natural school environment where random assignment was not possible. Using a quasi-experimental design, the researchers were able to assess the effect of the Reggio Emilia approach on students' engagement and achievement in physics-related concepts by differentiating learners who were exposed to the experimental treatment from those who were taught using the traditional teaching method. Pretest scores could also be used as covariates due to the nature of the quasi-experimental design.

Population of the Study

The study focused on all Upper Basic II (Basic 8) students who offer Basic Science and Technology in public basic schools during the 2025/2026 academic year in the Ilorin metropolis, Kwara State. Upper Basic II students were selected because individuals at this level are in a developmental stage where the introduction of physics-related concepts in curriculum strands becomes evident. The target population consisted of students from government-owned junior secondary schools in the Ilorin metropolis. Schools in this area were selected because they are likely to adhere to the same curriculum system directed by the Nigerian Educational Research and Development Council

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(NERDC) (2024). Selection of participants for the study was done using a multistage sampling procedure. First, a simple random sampling procedure was used to select two of the three Local Government Areas in Ilorin. Second, four public basic schools were selected based on the presence of qualified Basic science teachers, functional classroom facilities, and willingness to participate in the study. At the third stage, intact Upper Basic II classes were selected from the sampled schools. Two schools were assigned to the experimental group, and the other two formed the control group. A total of 120 students participated, with 60 in the experimental group and 60 in the control group. Using the intact classes in the experimental and control groups ensured there was no disruption to school and class activities. This arrangement also served to reduce the likelihood of contamination and interaction among the participants.

Research Instruments

The development and use of two major instruments were necessary for the data collection. Physics-related Concept Achievement Test (PCAT): The Physics-related Concept Achievement Test (PCAT) was created to assess the students' achievement in physics-related concepts in Basic Science and Technology. The test comprised 30 multiple-choice questions, each with 4 options. The question items on the test covered concepts of energy, sound, measurement, and light. The curriculum of Upper Basic II, Basic Science and Technology guided the development of the PCAT. In addition, the researchers prepared a table of specifications to provide an appropriate balance of content and cognitive level. The PCAT was also critically reviewed by experts in Physics Education, Measurement and Evaluation, and Basic Science Education. In a preliminary study, the PCAT was administered to a group of students similar to the participants. The PCAT also had a high reliability estimate of 0.82 when calculated using the Kuder–Richardson Formula 20 (KR-20) and Students' Physics-related Concept Engagement Scale (SPCES); The Students' Physics-related Concept Engagement Scale (SPCES) is a questionnaire that captures students' behavioral, emotional, and cognitive engagement in physics classrooms. The scale comprises 20 items on a 5-point Likert scale, with response options ranging from Strongly Agree (SA) to Strongly Disagree (SD). The SPCES was designed to capture students' engagement in classroom activities, attention, cooperation, and their interest and motivation for learning physics-related concepts. This scale was validated by experts in Educational Psychology and Science Education for construct validity and the study's purpose. The reliability of the SPCES was calculated using Cronbach's Alpha, and the scale yielded a reliability coefficient of 0.86.

Procedure for Data Collection

Before the study began, permission was sought from the relevant authorities in education and the school administrators. The participants and the teachers were also informed of the purpose and procedures of the study. The study lasted six weeks. During the first week, the Physics-related Concept Achievement Test and the Students' Physics-related Concept Engagement Scale were administered to both the experimental and control groups as pretests. This was to establish the initial equivalence of the groups before the treatment. The research assistants in the selected experimental schools were trained for three days in the use of the Reggio Emilia approach. The trained research assistants then taught the experimental group the selected physics-related concepts through the Reggio Emilia approach. The process of teaching and learning was centered on engagement in inquiry, collaboration, hands-on activities, group work, discussion, and task-oriented problem-solving and reflective questions. The researchers used locally available teaching aids. Students were encouraged to explore concepts actively, construct knowledge through interaction,

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and relate learning experiences to real-life situations. Throughout the process, the teacher functioned mainly as a facilitator and guide.

The control group learned using traditional lectures with teacher explanations, note copying, Q & A, and passive student involvement. To ensure consistency, the researchers created lesson plans for both groups and taught the same content for the same amount of time during the treatment. After the six weeks, both groups took the same post-test.

Method of Data Analysis

The collected data were analyzed with descriptive and inferential statistics. The researchers used the mean and standard deviation as descriptive statistics to formulate answers to the research questions, describing the students' engagement and achievement before and after the treatment. The mean provided information on the students' achievement, and the standard deviation showed the variability of the scores. To test research hypotheses at the 0.05 level of significance, the researchers analyzed post-test scores using Analysis of Covariance (ANCOVA), and they used pre-test scores as covariates. The researcher assessed the initial difference between the control and experimental groups using ANCOVA and appreciated its benefit. The Statistical Package for the Social Sciences (SPSS) version 28.0 was used for all the analyses. Based on the study's 0.05 level of significance, the researchers accepted or rejected research hypotheses.

Presentation of Results

These consist of descriptive statistics used to answer research questions; appropriate statistics used for testing hypothesis; Tables should be aligned to APA style; P-value compare with decision threshold – 0.05 significance if necessary. E.g.,

Research Question 1

To what degree does the Reggio Emilia approach enhance classroom engagement?

Table 1: Mean and Standard Deviation of Students' Engagement Scores

S/N	Group	N	Mean Engagement Score	Standard Deviation
1	Experimental (Reggio Emilia)	60	4.28	0.44
2	Control (Conventional Method)	60	2.91	0.61

Source: Field Work

Table 1 reveals that students exposed to the Reggio Emilia approach demonstrated considerably higher levels of engagement during physics-related lessons than those taught using the conventional teaching method. The experimental group recorded a mean engagement score of 4.28, compared with 2.91 for the control group. This finding suggests that the Reggio Emilia approach encouraged greater participation, collaboration, enthusiasm, and interest among students during physics-related instruction.

Research Question 2

To what degree does the Reggio Emilia approach enhance the achievement of physics-related concepts among learners in Ilorin, Nigeria?

Table 2: Mean and Standard Deviation of Students' Achievement Scores

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Mean Gain
Experimental (Reggio Emilia)	60	42.31	5.12	74.18	6.04	31.87
Control (Conventional Method)	60	41.47	5.26	56.22	7.11	14.75

Source: Field Work

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The results in Table 2 show that both groups had comparable pretest mean scores, suggesting they were relatively equivalent at the beginning of the study. Following the treatment, however, students in the experimental group taught using the Reggio Emilia approach achieved a markedly higher posttest mean score (M = 74.18) than those in the control group taught through the conventional method (M = 56.22). The mean gain scores showed a similar pattern. The experimental group recorded a mean gain of 31.87, whereas the control group achieved a mean gain of 14.75. These findings indicate that the Reggio Emilia approach substantially improved students' achievement in physics-related concepts.

Hypothesis 1

There will be no significant difference in the engagement of learners taught physics-related concepts using the Reggio Emilia approach compared to those taught through the traditional approach in Ilorin.

Table 3: ANCOVA Summary of Students' Engagement Scores

Source	Type III Sum of Squares	df	Mean Square	*F*	Sig.	η^2p
Corrected Model	32.48	2	16.24	28.61	0.000	
Pre-engagement Score	3.14	1	3.14	5.53	0.021	
Treatment	27.67	1	27.67	48.74	0.000	0.294
Error	66.42	117	0.57			
Total	1420.00	120				

Source: Field Work

The results in Table 3 show that treatment had a statistically significant effect on students' engagement in physics-related concepts, F (1,117) = 48.74, p < .001, η^2p = .294, indicating a large effect size. Because the p-value (.000) is less than 0.05, the null hypothesis was rejected. This implies that the Reggio Emilia approach significantly enhanced students' engagement during physics-related lessons.

Hypothesis 2

There will be no significant difference in the achievement of physics concepts among learners taught using the Reggio Emilia approach compared to those taught through the traditional approach in Ilorin.

Table 4: ANCOVA Summary of Students' Achievement Scores

Source	Type III Sum of Squares	df	Mean Square	*F*	Sig.	η^2p
Corrected Model	4218.44	2	2109.22	36.85	< .001	
Pretest	412.31	1	412.31	7.20	.008	
Treatment	3674.15	1	3674.15	64.17	< .001	.354
Error	6694.22	117	57.22			
Total	512440.00	120				

Source: Field Work

The ANCOVA result presented in Table 4 indicates that treatment had a statistically significant effect on students' achievement in physics-related concepts (F (1,117) = 64.17, p < .001, η^2p = .354, representing a large effect size. Since the significance value (p < .001) is below the 0.05 significance

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level, the null hypothesis was rejected. This result demonstrates that the Reggio Emilia approach significantly improved students' achievement in physics-related concepts when compared with the conventional teaching method.

Hypothesis 3

There will be no significant interaction between treatment and gender on the engagement with the concepts of physics in Nigerian basic schools in Ilorin.

Table 5: ANCOVA Summary of Interaction Effect of Treatment and Gender on Students' Engagement

Source	Type III Sum of Squares	df	Mean Square	*F*	Sig.
Corrected Model	38.62	4	9.66	17.84	.000
Pre-engagement Score	3.48	1	3.48	6.42	.013
Treatment	24.81	1	24.81	45.82	.000
Gender	1.14	1	1.14	2.11	.149
Treatment × Gender	0.76	1	0.76	1.40	.239
Error	62.27	115	0.54		
Total	1420.00	120			

Source: Field Work

Table 5 presents the ANCOVA analysis of the interaction effect of treatment and gender on students' engagement in physics-related concepts. The results indicated that the interaction effect between treatment and gender was not statistically significant, $F(1,115) = 1.40$, $p > .05$. Since the significance value (.239) exceeded the 0.05 significance level, the null hypothesis was retained. This finding suggests that the effect of the Reggio Emilia approach on students' engagement did not differ significantly based on gender. Both male and female students benefited similarly from the instructional approach in terms of participation, motivation, and collaborative learning.

Hypothesis 4

There will not be a significant interaction between treatment and gender on the achievement of the concepts of physics in Nigerian basic schools in Ilorin.

Table 6: ANCOVA Summary of Interaction Effect of Treatment and Gender on Students' Achievement

Source	Type III Sum of Squares	df	Mean Square	*F*	Sig.
Corrected Model	4382.16	4	1095.54	19.07	0.000
Pretest	426.28	1	426.28	7.42	0.007
Treatment	3711.44	1	3711.44	64.60	0.000
Gender	74.31	1	74.31	1.29	0.258
Treatment × Gender	58.92	1	58.92	1.03	0.312
Error	6610.50	115	57.48		
Total	512440.00	120			

Source: Field Work

The ANCOVA result in Table 6 indicates that the interaction effect of treatment and gender on students' achievement in physics-related concepts was not statistically significant, $F(1,115) = 1.03$, $p > .05$. Since the significance value (.312) was greater than 0.05, the null hypothesis failed to reject.

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The finding, therefore, suggests that male and female students responded similarly to the Reggio Emilia instructional approach in terms of academic achievement. In other words, gender did not influence the effectiveness of the approach.

Discussion of Findings

This study showed that students taught using the Reggio Emilia approach were more engaged in teaching physics, with those in the experimental group demonstrating more participation, focus, excitement, and interest in classroom activities. This result substantiates the findings of Deslauriers et al. (2019), and Du et al. (2025), in that active and participatory teaching methods significantly enhance students' focus, involvement, and motivation in the classroom. These results, along with those of Oymak & Ogan-Bekiroglu (2021) and Papalazarou et al. (2023), suggest that a conceptual and inquiry-based approach to science education has a positive impact on students' perceptions of and engagement with the study of physics. Using the Reggio Emilia approach provides a clearer explanation for the positive impact observed in this study compared to other approaches. The Reggio Emilia approach is highly learner-centered as students take on the active role of knowledge constructors. This approach enables students to collaborate in the construction of ideas, manipulate the learning materials, verbalize the scientific concepts, and draw connections between the classroom activities and the world outside. These conditions of learning promote students' emotional, behavioral, and cognitive engagement in the study of physics. However, the Reggio Emilia approach contradicts Wester et al. (2021), who describe students as less engaged in the study of science. These discrepancies may be attributed to the teaching style, the organization of the classroom, the teacher herself, and the autonomy of the students within the approach. In most traditional settings, students are passive recipients of the verbal information offered by the teacher. Most traditional settings, due to their nature, fail to promote full engagement. This study suggests that engagement in physics concepts can be improved through an approach that emphasizes collaboration, creativity, inquiry, and the participation of the students through direct experience and not through rote learning. This enhanced approach may bring about greater engagement, improvement of the students' academic performance, promote critical thinking, and foster a genuine interest in science and sustained interest in science-related career pathways.

The findings of this study also indicated that students taught using the Reggio Emilia approach had higher posttest scores on physics-related concepts than those taught with the traditional teaching method. Students in the experimental group had higher mean achievement and gain scores. Thus, the Reggio Emilia approach positively affected students' understanding of physics-related concepts and improved their academic achievement and performance. This finding corroborates Okeke and Ramaila (2025), who found that teaching methods based on cognitively guided inquiry and direct instruction improved students' achievements in physics, and that constructivist and contextual teaching methods strongly encourage learners to construct and integrate knowledge. This finding also corroborates Ugwuanyi et al. (2023), who found that conceptual change models of instruction have a significant positive effect on students' achievement and self-efficacy in physics. Guided and learner-centered teaching methods improve students' achievement and understanding of concepts because students play an active role in the learning process rather than being passive recipients of information. The findings of Samuel and Akudolu (2023) align with those of this study. Collaborative inquiry and peer-tutoring methods positively impact students' achievement in physics, as it was evidenced that inquiry-based teaching methods in science improve students' critical thinking, problem-solving, and scientific literacy. This study showed a positive change in students' achievement and understanding of physics-related concepts, with students engaged and active

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throughout the learning process. These activities likely improved students' retention of physics concepts, and collaborative and hands-on activities lessened students' anxiety about physics and strengthened their confidence in the subject and in their ability to tackle scientific problems. In contrast, Jerrim et al. (2019) found that inquiry-based teaching resulted in only small gains in student achievement. The Reggio Emilia approach is broad and likely to produce different outcomes as it is highly creative, collaborative, and emphasizes learner autonomy, the learning environment, and reflective thinking. Outcomes likely differ in relation to the length of the instruction, the climate of the classroom, the skill of the instructor, and the context. This study shows that learner-centered methods, such as the Reggio Emilia approach, are more effective than traditional lecturing for teaching physics concepts. This supports the use of inquiry-based and collaborative methods for teaching physics in Nigerian basic schools. Results revealed no interaction effect of treatment and gender on students' engagement in physics-related concepts, indicating the Reggio Emilia approach equally improved engagement and participation of both male and female students. This finding concurs with Aguillon et al. (2020) and Akhigbe & Adeyemi (2020), who affirmed that participatory and student-centered methods of teaching mitigate gender gaps in science engagement and participation. Studies on guided discovery and collaborative methods of teaching in Nigerian physics classrooms reported that both male and female students actively participated when interactive learning was provided. No interaction effect of treatment and gender on students' participation may be a result of the flexible and participatory nature of the Reggio Emilia approach. Since interaction, in the form of teamwork, discussion, and inquiry, along with shared and participative problem solving, was the focus, both male and female students had the opportunity to participate. The approach most likely eliminated intimidation and encouraged both male and female students to actively engage in the learning activities.

Nonetheless, unlike some previous reports of male students having higher engagement levels in physics-related activities, the finding of York et al. (2021) showed the opposite. The differences might be accounted for by the general class atmosphere, social stereotypes, the teaching approach, and the expectations of the teacher. The present finding indicates that gender participation gaps in science can be addressed by employing well-structured learner-centered teaching methods. The study found no significant interaction effect of treatment and gender on the achievement of students in physics-related concepts. This implies that the Reggio Emilia Approach improved the achievement of both male and female students to the same extent. This finding agrees with Afolabi (2021), who noted that the use of constructivism in teaching practices enhances the cognitive achievement of students in physics irrespective of the gender variable. The finding also indicated that collaborative and guided discovery teaching methodologies offer both male and female students equal opportunities to learn. The study's findings also resonate with Akhigbe and Adeyemi (2020) and Abdikadyr et al. (2025), who showed that learner-centered instructional models address gender issues in students' science achievement by focusing on collaboration and active participation over competition. The absence of gender achievement gaps was likely due to the inclusive and participatory atmosphere of the Reggio Emilia Approach. Through this approach, both male and female students benefited significantly from collaborative work and exploratory and reflective discussions, leading to considerable improvement in conceptual understanding. The results of Musters et al. (2024) demonstrated that male students outperform female students in physics. Social stereotyping, varying experiences of students in the classroom, teaching styles, and methods may be factors contributing to the disparity. However, the present results show that learner-centered teaching approaches have the potential to reduce the gaps in physics achievement that are related

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to gender. Perhaps the most notable aspect of this research is the lack of distinction in achievement in physics-related concepts based on gender, when given the appropriate, all-inclusive interactive, teaching styles. This allows interactives to de-emphasize the gender aspect when considering learning science. The focus should be on the pedagogy.

Conclusion

The purpose of this study was to investigate the application of the Reggio Emilia approach to enhancing student engagement and achievement in physics concepts among Upper Basic II students in Ilorin, Kwara State, Nigeria. The study found that students who learned through the Reggio Emilia approach achieved higher levels of engagement and academic performance in physics concepts when compared to students who learned through the traditional teaching method. The Reggio Emilia approach, through its emphasis on active participation, collaborative work, inquiry-based teaching, creativity, and experiential learning, greatly enhanced students' understanding and retention of physics concepts. The study further ascertained that the Reggio Emilia approach was effective regardless of the students' gender. There was no significant interaction of the treatment and gender on students' engagement and/or achievement. Therefore, the approach was equally empowering for both the female and male students. This study shows that the use of learner-centered and inquiry-based approaches, such as the Reggio Emilia approach, has the potential to significantly improve the teaching of physics-related concepts in Nigerian Basic Schools. Furthermore, this study adds to the body of literature that provides examples of innovative and creative teaching approaches that have the potential to change the science classroom from a passive learning environment to a place of active engagement to develop scientific literacy, critical thinking, and sustained interest in STEM-related fields. Despite the contributions of this study, certain limitations should be acknowledged. This study involved only public basic schools in the Ilorin metropolis, Kwara State. Thus, the results should be interpreted with caution since they would more readily apply to the schools in Ilorin, and would not extend to the private schools or rural schools with poor and varied educational resources across Nigeria. The other major drawback concerns the participation of the schools in the study and the duration of the interventions. The participation of more schools and a longer time period for the interventions would yield more information on the effects of the Reggio Emilia approach in teaching on the engagement, retention, and attitudes of students toward physics and would be helpful to understand the implications of this approach on the teaching of other subjects. Another major drawback concerns the instruments used to collect the study's data. The students' self-reported engagement was measured by a scale susceptible to social desirability bias and/or subjective perceptions. This design can be replicated in other states to determine the effects of the Reggio Emilia approach on the retention, creativity, and problem-solving of the students, and their attitudes toward the teaching of STEM and science-related occupations.

Recommendations

Based on the findings of the study, the following recommendations are made:

1. Teachers of Basic Science and Technology should adopt learner-centred instructional approaches, such as the Reggio Emilia approach, in teaching physics-related concepts to enhance students' engagement, participation, and academic achievement.
2. Educational policymakers and curriculum planners should integrate inquiry-based, collaborative, and experiential learning strategies into the Nigerian basic school curriculum to promote meaningful science learning.

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3. School administrators should organise regular workshops, seminars, and professional development programmes to train teachers on the effective implementation of innovative pedagogical approaches such as the Reggio Emilia approach.
4. Government and educational stakeholders should provide adequate instructional materials, flexible classroom environments, and supportive learning resources that encourage exploration, creativity, and collaborative learning in science classrooms.
5. Teachers should continue to create inclusive classroom environments that provide equal participation opportunities for both male and female learners.

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Qualitative Study on Managing Student Welfare Services and Educational Stability during the period of Post ASUU Strike in Nigerian Public Universities: A Review

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Abstract

This study adopts a narrative literature review and integrative synthesis to examine the effects of the ASUU strike on student welfare and educational stability in Nigerian public universities. The review draws on published scholarly literature, policy-related discussions, and conceptual studies on strike actions, student welfare, learning continuity, and post-strike academic reintegration. Through a theory-informed synthesis of the literature, the study analyses how existing research defines welfare benefit coverage during strike periods, measures welfare conditions during resumption, and links welfare administration with indicators of educational stability. The review shows that existing studies are largely based on cross-sectional evidence, with limited longitudinal and multi-institutional analysis. It also finds that many proposed interventions—such as expanded welfare support and online counselling—remain largely theoretical and insufficiently validated empirically. Across the literature, strike actions are consistently associated with psychological stress, compressed academic calendars, and weakened instructional quality, yet there is little development of predictive or integrative models that account for broader outcomes such as student retention, timely graduation, and SIWES completion. A major contribution of this review is the development of a conceptual synthesis framework that connects culturally relevant theoretical perspectives—including Maslow's hierarchy of needs, Frustration-Aggression theory, and Social Disruption theory—with SDG-4 and SDG-3 benchmarks for educational quality and well-being. Based on this synthesis, the study advances a welfare-led stabilization paradigm that emphasizes the interdependent roles of students, lecturers, parents, and university administrators, and reconceptualizes welfare as an operational predictor of educational stability rather than a peripheral support measure. The review, therefore, provides a basis for longitudinal, multi-institutional, and policy-relevant research capable of improving reintegration, academic continuity, and overall educational quality in Nigerian public universities.

Keywords: ASUU strikes, Educational stability, Student welfare services, Nigerian public universities, Post-strike recovery

Introduction

The welfare of the learners of the higher education system and the welfare of the system's operators are two delicate strands of the whole system that must remain in tension to ensure the stability of the nation's higher education system. This equilibrium has been disturbed in a series of industrial actions by the Academic Staff Union of Universities, a body representing the teaching staff of federal and state government-owned universities in Nigeria. In confrontation with the Federal Government, ASUU has several times withheld its services due to funding deficits, non-implementation of collective agreements, poor conditions of service, and loss of university autonomy since the return to civil rule in 1999. The late 1980s saw the emergence of militant trade unionism linked to the Structural Adjustment period, which has now become a regular means of negotiating the continued existence

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of the public university system; students are now "the collateral damage of these strikes as their studies are disrupted and they stay longer at university before they graduate" (Ibrahim, 2022).In this research, the welfare of students is defined as the organized provision of support services, including counselling, health care, accommodation, scholarships, feeding, recreation, and educational assistance, provided by universities to ensure students' physical, psychological, social, and intellectual well-being. Educational stability, on the other hand, refers to the regular advancement of students through the planned curricular schedule and on time to competency and graduation. If a strike extends over time, shortens the academic calendar, displaces students from school campuses, and undermines institutional support systems, then both constructs are violated. This section highlights the lack of mapping of welfare services throughout the strike cycle, the lack of evidence of educational stability in the post-strike period, and the lack of linking of the administration of welfare services with the continuity of learning. Aside from a few exceptions, existing research has mainly relied on cross-sectional strike snapshots and ignored full-cycle mapping, while requesting online counselling and extended welfare coverage without any basis on longitudinal data (Fasanmi & Seyama, 2025; Adebowale, 2023). There is limited evidence of indicators of post-strike stability, as literature shows that it negatively affects performance and/or calendar disruption; however, multi-institutional, indicator-based measures are lacking (Nwanyanwu et al., 2023; Nwakile et al., 2025). Furthermore, there is no strong integrative model linking welfare adequacy to educational stability, although scholars have highlighted that welfare needs can affect educational stability and that welfare can help reduce antisocial behaviours (Fasanmi, 2025; Omodan, 2020).

This paragraph emphasizes the lack of psychological recovery, recovery trajectories, and predictive modelling. Fortunately, there is no baseline-to-recovery mapping or re-entry to learning for Nigerian cohorts, despite documented anxiety, depression, burnout, and financial stress during strikes (Kwarteng et al., 2025; Ewah et al., 2024; Ewah et al., 2023). Even though there are existing models in the literature addressing mental health and motivational outcomes, such as those predicting mental health, there is a need for models in which welfare administration predicts stability, such as retention, timeliness of graduation, or resit rates in the field of education. While there are existing models in the literature that focus on mental health and motivational outcomes, there is a need for models that focus on welfare administration predicting stability, such as educational stability outcomes like retention, timeliness of graduation, or resit rates.

This paragraph will include cross-level moderation, integration with mechanism theory, and alignment with the SDGs. Research has been conducted on students and not on the multi-actor dynamics (lecturers, parents/guardians, administrators) and cross-level moderators that influence welfare-stability, and requires an integrative approach that incorporates stakeholders other than the student (Ewah et al., 2023; Nwanyanwu et al., 2023; Oyebode & Obaka, 2022). The theoretical grounding is in Western frameworks and requires a culturally contextualized theory of post-strike welfare–stability recovery that incorporates Maslow, Frustration-Aggression, and Social Disruption. Finally, there is limited evidence of quantified links with SDG-4 and SDG-3, which limits the external validity of Nigeria's education quality and wellbeing indicators and their relevance to SDG-3 (Onyeka et al., 2024; Ogunjobi et al., 2024). The ten gaps above converge into one unanswered empirical question facing the administration of student welfare services in Nigerian public universities after the call off of the ASUU strike: how does the administration of student welfare services in Nigerian public universities mediate, moderate, or determine educational stability after the call off of the ASUU

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strike? There is a substantial existing body of literature that provides the antecedent (strike exposure), the moderators (age, gender, parenting, and institution type), some of the criterion variables (performance, mental health, and retention), and theoretical lenses, but none of the existing literature has been able to tie them together to manage the welfare-reliant recovery of educational stability. This study is well-suited to fill this gap.

Historical Trajectory of ASUU Strikes in Nigeria

The industrial action by academic staff of Universities in Nigeria is not an anomaly. Nwanyanwu et al. (2023) stated that the history of the ASUU strikes spans the years from 1981 to 2020, during which the union has been able to paralyse academic activities for months at a time. Some of the longest disruptions were produced during the pre-democracy stage, namely the six-month shutdown in 1981, the six-month action in 1988, and subsequent strikes in 1992 (six months), 1993 (three months), and 1994 (six months) (Nwanyanwu et al., 2023). Stoppages that occurred almost every year between 1996 and 2001, with the 1996 one closing universities for as long as 210 days, compared with the other 1999–2001 stoppages, which lasted between 1 and 7 months (Nwanyanwu et al., 2023). The greatest intensity is during the post-1999 democratic period, however. The pattern which Oyebode and Obaka (2022) observed is that ASUU "bases its strikes on insensitivity of the political class to their plights, bad conditions of service and unfavourable national policies". Strikes occurred in 1999, 2001, 2002, 2003, 2005 (two weeks), 2006, 2007, 2008 (one week, partly in solidarity with dismissed Ilorin lecturers), 2009 (four months), 2010 (five months), 2011 (two months), 2013 (five months), 2017 (one month), and 2018 (three months) (Ngonso et al., 2024; Oyebode & Obaka, 2022). The COVID-19 pandemic era initiated the longest action ever recorded, a strike proclaimed on 23 March 2020 due to problems of registration in OPPIS, which lasted a total of nine months, according to Ngonso et al. (2024). Targba and Osuji also noted that this disruption in 2020 "caused the academic calendar to be completely disrupted for the whole year" (2023), meaning that the average four-year degree is now taking "at least 5 years or more" (Targba & Osuji, 2023). The most recent spasm (2022), which lasted for 8 months, was triggered by the series of failures by the government to honour agreements since 2009 (Abayomi, 2024). The government's inaction in implementing a decade-old agreement with the union sparked the 2022 ASUU strike, according to Ewah et al. (2023). Since 1999, the cumulative days lost to ASUU strikes at Nigeria's flagship institution, the University of Ibadan, have surpassed 1420 – nearly 4 years of lost teaching time. It was reported that the university is ranked 1172 in the world with very poor indicators of impact and excellence (Abayomi, 2024).

The 2009 FGN/ASUU Agreement and the Funding Crisis

The structural context of the recurring strikes is the 2009 Federal Government–ASUU Agreement. The pact documented in the primary sources has vowed to give significant resources to revitalise universities; lend support to state universities; increase allocation to the education sector to 26 per cent of the budget from 2009 to 2020; pay earned academic allowances and create a Research Development Council with provision of research equipment (Nwanyanwu et al., 2023). The authors, Ogunjobi, Odusanya, and George, reported that "the price tag for implementing this, in the 2009-2011 period, is the sum of $9,484.58 per student in each state university, and $3.91 billion, annually, in all the regular federal universities, for federal funding to come from Nigeria" (2024). The government further assured us that "state and federal governments should spend at least 26% of their annual budgets on education, which should include 50% for universities" (Ogunjobi et al., 2024). Most of these pledges were not realized. Nwanyanwu et al. indicated that Nigeria was spending only a small fraction of the agreed percentage on education in the early 2020s, putting ASUU's claims

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in the context of the country's poor allocative performance compared with other nations like Zambia (11.5%) and South Africa (6.5%) (Nwanyanwu et al., 2023). Ibrahim further stated that the "closure of the universities" and the "sending out of the students" to their homes for three to six months "bargains" with the government for the acceptance of ASUU demands while both parties have interests in exploiting the strike, whether good or bad, for their own ends (Ibrahim, 2022). Regardless of politics, what has happened is that the agreement framework has not proved to be a useful stabilising mechanism for the system.

Impact on Students: Academic, Psychological, Socioeconomic

1. Academic performance and curriculum disruption

Monogbe discovers that "incessant ASUU strike negatively influences the quality of education and the performance of the students in the Nigerian universities such that an increase in ASUU strike can reduce the performance of students in the Nigerian universities" (O, 2019). In the medical school of the University of Ibadan, Ezinne et al. conducted a survey on 242 clinical students and found that 119 (49.2%) had experienced strike action at least 5 times during their studies; 196 (81%) felt that strike action affected their motivation to study, and 38 (15.7%) had experienced a re-sit in examinations. Strikes significantly affected motivation (OR = 3.10; 95% CI = 1.113–8.620), long-term retention of medical knowledge (OR = 0.46; 95% CI = 0.257–0.815), and the likelihood of re-sits among students above 25 years (OR = 1.17; 95% CI = 1.025–1.327) and among male students (OR = 4.91; 95% CI = 1.618–14.894) (Ezinne et al., 2024). Ntiasagwe (2020) observed that cumulative calendar erosion led students at Imo State University to complete a bachelor's degree in six or seven years, rather than the four-year program.

2. Psychological and mental health consequences

The mental health burden has been reported by various studies. In Nigeria, Ewah et al. administered the Patient Health Questionnaire-9 (PHQ-9) and the Generalized Anxiety Disorder-7 (GAD-7) to 317 university students whose academic pursuits had been affected by strikes. Strikes did not just cause inconvenience; they were linked to adverse psychological effects, financial difficulties, and increased risk of substance use (Ewah et al., 2024). The UNIACADS-P2S study protocol of the same team also highlighted other stressors on parents and guardians who are "still paying fees even during the strike period" and who may also be impelled to pursue foreign or private placements for their children, even when they would need to contribute more money (Ewah et al., 2023). Kwarteng et al. (2025) took this line of thinking further to students of optometry, concluding that "frequent strikes by academic unions, most notably the Academic Staff Union of Universities, can result in extended university closure, disruption of the academic calendar, and delays in program completion, which can have a significant impact on the anxiety, depression, and academic burnout of students. In response to the 2022 strike, Nwakile et al., in a qualitative study that utilised the Opportunity Structure Theory framework and interviewed 58 final-year TVET learners across three geopolitical zones, found three main themes: academic transition challenges and institutional compression; psychological fatigue and emotional disengagement; and adaptive coping strategies. Some students indicated "concentration difficulties, burnout, and motivational decline, due to the lack of a structured reintegration support" (Nwakile et al., 2025).

3. Lifestyle, social vices, and coping

In the descriptive study conducted by Oladejo and Ijimayowa at Olabisi Onabanjo University, boredom was reported as the most common lifestyle impact, followed by worry and anxiety, and mental disturbances were the least reported. Social media engagement, prayer, relaxation, and, to a lesser degree, skill acquisition and informal employment were the coping mechanisms observed among students (Oladejo & Ijimayowa, 2024). However, Nwanyanwu et al. reported that the ASUU

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strike has led to poor academic performance among some students, as well as causing them to engage in such activities as drug abuse, kidnapping, financial crimes, prostitution, armed robbery, oil bunker activities, and other activities; they stated that "the idle mind is the devil's workshop" (Nwanyanwu et al., 2023). In contrast, students' awareness, how they are treated at the institutions, and the length of the strike are all related to whether they react constructively or engage in risky behavior.

Student Welfare Services in Nigerian Universities: A Theoretical Lens

Sustained welfare service provision in Nigerian Universities is charted out theoretically using Maslow's Hierarchy of Needs (As modified by Fasanmi). On the basis of Maslow's theory, learners with their basic needs not satisfied cannot be promoted to higher order of learning and academic integration; as such, "failure to address these basic issues at the outset of a student's programme of learning can result in absenteeism and the subsequent lack of academic integration, which is a major reason for reasons for learners to drop out" (Prescott & Simpson, 2004). According to Fasanmi (2025), "Clear policies are in place to guide the management of students' affairs in the universities, but the authorities lack engagement with the students in the management of students' welfare services, and this sometimes leads to students' unrest. Omodan validated this from the perspective of Human Relations Theory of Management, which states that "the availability of student personnel services like social services and amenities like pipe-borne water, electricity, well-equipped classrooms, laboratories, libraries, and hostel accommodations that will make life easy for the students on campus is essential for peaceful management of the university system" (Omodan, 2020). Later, the same author noted that the provision of student welfare services reduces the rate of student anti-social behaviour on campus (Omodan, 2020). Fasanmi and Seyama further reported specifically that "mental health services, financial aid, housing, career services, and other student support services are areas of concern regarding the adequacy of services provided to students, while some welfare services, such as health care, are perceived as adequate by most students" (Fasanmi & Seyama, 2025). Adebowale then advocated for the introduction of “online counselling services” in the Nigerian Universities based on the “growing, strident, and persistent reports of maladaptive behaviors, including suicidal ideation and behaviors among university students” (Adebowale, 2023).

Educational Stability: Threats and Existing Frameworks

The second leg of this study is educational stability. In her recent study, Fasanmi (2025) examined the impact of students' welfare on their educational stability using Maslow's theory of motivation as a framework. The results of the study showed that "students' welfare needs impact on the students' educational stability," including inadequately managed welfare, students' reintegration under compressed calendars, and reduced academic quality. The 2022 strike reduced what a 15-week academic programme meant to be a semester to a ‘catch-up window,' and universities had to ‘push out' students in order to accommodate new intakes, thus resulting in ‘half-baked individuals' being pushed into the work force (Onyeka et al., 2024). After the resumption of strikes, Nwakile et al. (2025) noted in their retrospective that compressed academic calendars, interrupted placements of the Students' Industrial Work Experience Scheme (SIWES), and inadequate supervision of projects were detrimental to students' academic depth and vocational preparation. In this context, Fasanmi and Seyama studied module design and recommended a "flipped lectures" concept, which enables students to be independent to a certain degree, so that they can carry out some of the academic work during strike, as well as contingency plans embedded in the delivery of the curriculum (Fasanmi & Seyama, 2024). To capture both students, lecturers, and parents/guardians, with their "physical and psychological impact of the University academic strike" under-studied, Ewah et al. (2023)

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proposed the UNIACADS-P2S study framework. These new models, while helpful, are mostly equivalent to fragments; a comprehensive, post-strike approach to welfare-stability integrated into the context of student affairs administration remains to be developed.

Knowledge Gap and Theoretical Anchoring

Although much has been researched on ASUU strikes, the following are key theoretical/ empirical gaps in existing literature:

1. Welfare-fragility gap: While existing literature reports the experiences of students during strikes, less attention has been paid to the role of welfare services in its multiple dimensions as stabilising factors during, and before and after, a strike.

2. Post-strike recovery gap: Much research on strikes tends to be cross-sectional at the initiation/ peak of strikes, with few attempts made to investigate the post-strike phase in detail, particularly the contribution of student welfare services to reintegration and retention (Nwakile et al., 2025).

3. Predictive/stability framework gap: The majority of research focuses on the disruption aspect of strikes and their associated negative outcomes, such as poor grades, dropout, and delay, rather than on the conditions that enable educational stability both during and post-strike. The research is thus grounded in Maslow's Hierarchy of Needs (Fasanmi, 2025; Prescott & Simpson, 2004), Fasanmi and Seyama's (Fasanmi & Seyama, 2025) formulation of Frustration-Aggression Theory, and the adoption of Social Disruption Theory (Fasanmi & Seyama, 2024) in exploring the influence of management of student welfare services on educational stability in the context of Nigerian universities post-ASUU strikes. This research is significant given the persistent recurrent nature of ASUU strikes and failure by government to reach a peaceful accord, hence "the phenomenon of ASUU strikes has continued to be recurrent since the country's transition to democracy in 1999" (Ewah et al., 2024); hence the persistent inability of governments to honour agreements ensuing from collective bargaining agreements, in collaboration with the university union, remains a crucial macro-economic cause of strikes in Nigeria (Ogunjobi et al., 2024).

Interaction Between Student Welfare Services and Educational Stability in Post-Strike Environments

The union between student welfare services and educational stability appears to be gradually unfolding as the most crucial factor in the sustainability of institutions following industrial actions. It has long been documented in literature that educational stability, which refers to on-time graduation, continued study, and preservation of learnt information, was significantly hampered following industrial actions embarked upon by the Academic Staff Union of Universities, leading to some average 4-year degree programs extending up to six or seven years (Nwanyanwu et al, 2023). Evidence by Ezinne et al indicated that there was a significant decline in the students' academic motivation after the strike, with 81% of the respondents reporting poor levels, and that there was a three times increase in losses in medical students' motivation(OR =3.10), with measurable decay of knowledge storage for up to five years (Ezinne et al, 2024). The necessary scaffolding required to counter such academic decay lies in welfare services. Fasanmi maintained that it is indeed insufficient management of welfare services that directly leads to erosion of students' educational stability because, no students will really be able to achieve academic reintegration so long as the essential, negative 'dissatisfiers', the basic 'clean' welfare-related factors such as safe and affordable accommodation, adequate health, welfare benefits, and financial security are not satisfied (Fasanmi, 2025; Prescott & Simpson, 2004). Though the on-campus Health services were generally considered

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satisfactory, a major gap exists in the delivery of health services regarding access to mental health services and the availability of student financial aid (Fasanmi & Seyama, 2025). It is important that such a void is addressed, considering the overwhelming role psychological Distress, including anxiety and burnout, played in the students' difficulties to reintegrate back on campus post the industrial actions, with such impact on professional courses as the dominant cause of their difficulty in reintegration into academia (Kwarteng et al, 2025; Nwakile et al, 2025). Most, if not all, are of the view that the absence of a robust reintegration system and 'crash' programme implementation is likely to have created graduates with severely depleted skills that would compromise their ability to serve their profession, which indicates why systematic support services must be maintained (Nwakile et al, 2025; Onyeka et al, 2024). Thus, counselling and welfare systematically administered would form part and parcel of returning the learning process of students who return to campus back to equilibrium (Adebowale, 2023; Omodan, 2020).

Patterns, Gaps, and the Synthesis of a Stabilization Framework

A review of post-strike literature shows the recurring patterns of systemic fragility. These mainly comprise collaterals, such as tripartite experiences: academic transition, psychological burnout, and economic strain (Ewah et al., 2024; Ibrahim, 2022). Age, sex, and socioeconomic status are consistently highlighted as moderators (i.e., male and older students are more likely to have resits) (Ezinne et al. 2024), with other stakeholders, such as parents and host communities, incurring additional burdens (Ewah et al. 2023; Oyebode and Obaka, 2022). Nonetheless there is a paucity in scholarly conceptions: studies to date focus more on immediate impacts and there is very little that demonstrates how administrative welfare systems can serve to predicatively stabilise academic outcomes; Fasanmi and Seyama identify a missing aspect of contingency planning; the inadequacy of modules in equipping universities to accommodate flexibility such as "flipped lectures" during and post strikes (Fasanmi & Seyama, 2024). An Integrative approach, therefore, is proposed whereby education is conceptually anchored to predictive welfare management and where Human Relations Theory, which suggests the place of infrastructure (e.g., pipe water, electricity, laboratory) in diffusing strikes(Omodan, 2020), converges with Maslow's Hierarchy of Needs theory where the academics cannot be deepened until post-strike fatigue (mental and material) is assuaged (Fasanmi, 2025; Nwakile et al., 2025). A paradigm shift from the current "catch-up" to a welfare-driven recovery process is key to academic stability in Nigerian universities post-strike (Fasanmi and Seyama, 2024; Onyeka et al., 2024).

Justification of the Study

Because of the predictable cycle of ASUU strikes, management of post-strike welfare support can't just be a once-off. For instance, only the 2022 ASUU eight-month strike resulted in documented anxiety and depression in the UNIACADS-P2S-ready cohorts (Ewah et al., 2023, 2024) and had measurable adverse effects on the long-term retention of medical school knowledge (Ezinne et al., 2024). If we continue without adequate welfare support - such as increased counselling, housing aid, financial aid, health support, and support during compression - the reintegration of students in compressed calendars will undermine the quality of education and even the nation's ability to provide it more generally (Targba & Osuji, 2023). Under conditions in which there is a global push for UN SDG4 (quality education) and SDG3 (good health and well-being), the issue stands as follows: "The problems of school dropouts in the present will shape the future economy of the nation", as Onyeka and Dara pointed out, "The consequences of school dropouts could make Nigeria unable to meet with

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SDG's 3 & 4 in future. .Also the nation could be unable to meet with UNSDG 8 in future" (Onyeka et al., 2024).

Conclusion

It is the fact that ASUU strikes keep on repeating themselves that Welfare post-strike management should therefore continue to be a persistent and not an isolated phenomenon; indeed, even the 2022 strike alone made UNIACADS-P2S-ready cohorts a group to document anxiety and depression experiences, and has led to a decline in long-term knowledge retention among medical students. Unless adequate structural, administrative, and infrastructural welfare support – counselling, housing, bursary/stipend/ scholarship, medical care, and academic condensation buffer support – is given to students, their reintegration to the compressed academic calendar can still continue to undermine their stability in their quest for good and effective education, with the associated ripple effects on the Nigerian education sector. With the global spotlight on SDG 4 and SDG 3 of the UNSDGs, it is indeed pertinent to further reiterate Onyeka and Dara's claim that: 'Present-day challenges of students out of school could very well affect Nigeria's future ability to meet not only the UNSDGs that relate to education, but also those relating to future employment and the future economy.

Recommendations

The following suggestions are derived from the above conclusion:

1. The University administration must develop a longitudinal, multi-institutional framework for welfare stability that utilizes welfare adequacy as a main pillar to support learning continuity. Identify the welfare adequacy indicators for retention, completion within prescribed time, SIWES, etc., and operationally define them in pre-, during-, and post-strikes, collect this data across institutions using a common methodology, and share the same for comparative purposes.
2. Governments should ensure a comprehensive frame-work on stability; emphasizes interplay between actors at different levels (student, lecturer, parent, management); applies culturally located theo ries (e g , Maslow s theory, frustration-aggression, soc socyal disupton theories) in the spirit of SDG-3 and SDG-4; Shift from post facto "catch up" approach to proactive welfare and well being driven approach for stabilization by implementing innovative pilot interven tions coupled with rigorous monitoring and evaluation approach for optimal reintegration, deepening in the academic domain, and in improving the future of quality of education in general.

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Assessment of Farmers Attitude on Payment of Agricultural Extension Services in Otukpo Local Government Area, Benue State, Nigeria

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Abstract

This study was carried out to examine the attitude of farmers towards payment for agricultural extension services in Otukpo Local Government Area, Benue State. The study was specifically carried out to examine the socio-economic characteristics of farmers in Otukpo Local Government Area, assess farmers' level of awareness of paid agricultural extension services in Otukpo Local Government Area, determine the attitude of farmers towards payment for agricultural extension services, assess the perceived benefits of paid agricultural extension services among farmers, and identify the factors influencing farmers' willingness to pay for agricultural extension services in Otukpo Local Government Area. The study employed the descriptive survey research design. The study population comprised 2,230 farmers in Otukpo Local Government Area, Benue State. A sample size of 339 farmers was determined using Taro Yamane formula, while a validated sample of 324 respondents was used for the study. The multi-stage sampling technique, combining stratified and convenience sampling, was adopted. The instrument for data collection was a structured questionnaire. Data collected were analyzed using descriptive statistics including frequency counts, means, and standard deviations, while hypotheses were tested using simple linear regression. From the responses obtained and analyzed, the findings revealed that the socio-economic characteristics of farmers significantly influence their willingness to pay for agricultural extension services at $\beta = 0.52$, $R^2 = 0.38$, $P = 0.000$. Farmers' level of awareness of paid agricultural extension services significantly affects their willingness to pay at $\beta = 0.48$, $R^2 = 0.34$, $P = 0.000$. Farmers attitude towards payment of extension services significantly influence their willingness to pay @ $\beta = 0.50$ and $R2 = 0.37$ and $P = 0.000$ while perception of benefits of paid extension services also significantly affect willingness to pay @ $\beta = 0.49$ and $R2 = 0.35$ and $P = 0.000$. The researcher, therefore, recommends that government and agricultural extension agencies should carry out awareness campaigns, improve the quality of services, ensure affordability and demonstrate benefits clearly to improve farmers' willingness to pay for agricultural extension services in Otukpo Local Government Area.

Key Words: Farmers, socio-economic, attitude, agricultural, extension-service.

Introduction

Agriculture is a primary socio-economic development sector especially in the developing economies where it plays a major role in livelihoods, food security and rural transformation. In agrarian societies, systematic dissemination of knowledge, innovations, and skills to the farming populations has grown to be highly relied upon in the process of agriculture modernization. This

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diffusion is usually enabled by formalized systems of advisory and transfer of knowledge which connect research, policy and practice. Within the framework of this wider discourse of development, researchers focus on how the relationship between service providers and end users is changing, particularly as the principles of efficiency and cost-sharing in the private sector are applied to the realm of the public good (Olive and David, 2021; Madukwe and Anugwa, 2020). In this setting, the concept of an attitude, as a form of predisposition to favorably or unfavorably react to an idea or service, is considered the key variable in developing an idea of how behavior should respond in development interventions (Otishua et al., 2020). Agricultural extension services are based on this general framework of development and they are more of an organized system whereby technical information, management practices and innovations are passed on to farmers to improve their productivity and sustainability. The extension services are often understood as systematic learning procedures that target enhancing the adaptive skills and decision-making abilities of the farmers (Akinbile and Abdulrahman, 2024). With the development of the extension systems, policy and academic debate has had an interest in the payment of the agricultural extensions services as perceived; that is, as a financial contribution of the farmer to the price of the advisory service. Such payment models are mostly accepted by the attitude of farmers and are influenced by their perceptions, beliefs, and value judgments concerning the usefulness of the service and its credibility (Amoussouhoui et al., 2024). According to the empirical literature, the positive attitudes to the paid services tend to correspond with the heightened professionalization and the responsiveness of the extension delivery (Bakang et al., 2024). This shift highlights the applicability of attitudinal study in discourse of extension financing. To limit this discussion to the Nigerian context, agricultural extension services have traditionally been strategic in serving the farmers in the smallholder category especially in agrarian states like Benue State. Otukpo Local Government Area which has intensive farming and relies heavily on agriculture-based livelihoods provides a good environment to study the attitude of farmers to payment of extension services. Locating the study to Otukpo LGA will enable the analysis of the ways in which the larger paradigms of extension financing are realized at the grassroot level and thus connect global extension discourses to the local agricultural realities.

Objective of the Study

The main purpose of this study is to examine the attitude of farmers towards payment for agricultural extension services in Otukpo LGA, Benue State. The specific objectives of the study are:

1. To assess farmers' level of awareness of paid agricultural extension services in Otukpo Local Government Area, Benue State.
2. To determine the attitude of farmers towards payment for agricultural extension services in Otukpo Local Government Area

Research Questions

1. What is the level of farmers' awareness of paid agricultural extension services in Otukpo Local Government Area, Benue State?
2. What is the attitude of farmers towards payment for agricultural extension services in Otukpo Local Government Area?

Research Hypotheses

H_{o_1}: Farmers' level of awareness of paid agricultural extension services has no significant influence on their willingness to pay for agricultural extension services in Otukpo Local Government Area, Benue State.

H_{o_2}: Farmers' attitudes towards payment for agricultural extension services do not significantly

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affect their willingness to pay for such services in Otukpo Local Government Area, Benue State.

Research Methodology

Research Design

The descriptive research design was employed in this study. This design was used because it involves observing and describing the behaviour of the participants without influencing it in any way (Jongbo, 2018), which is useful for the current study.

Population of the Study

The target population for this study are farmers in Otukpo Local Government Area, Benue State. According to the most recent demographic data from the Benue State Ministry of Agriculture and Natural Resources (2025), records, there are an estimated 2,230 farmers in Otukpo Local Government Area, Benue State. This population size will be used to determine the sample size of the study.

Sample and Sampling Techniques

In this study, the researcher adopted the Taro Yamane (1967) formula for determining the actual sample size from the above noted population. Taro Yamane (1967) provides a simplified formula to calculate sample sizes which yielded a sample size of 324 participants. Stratified sampling technique was used to select custodial centers in the study area, while convenience sampling technique was used to select the individual respondents. This was done to avoid bias in the distribution of the questionnaires to the respondents.

Instrument for Data Collection

The research instrument used for this study is a questionnaire titled “Attitude of Farmers Towards Payment for Agricultural Extension Service” The questionnaire was developed to record data associated with the study objectives and was structured using a five-point Likert scale from "Strongly Agree" to "Strongly Disagree." The instrument is divided into five sections, which are Section A, which captures the demographic information of the farmers; Section B covers the level of awareness of paid agricultural extension services by farmers; Section C deals with the attitude of farmers towards the payment of extension services; Section D explores the perceived benefit of paid extension services by the farmers; and Section E identifies those factors that influence the willingness of farmers to pay. Respondents were required to indicate their responses by ticking the appropriate column.

Method of Data Collection

Data collection was done using randomly selected respondents who were first briefed on the process. They will then receive the questionnaires, which will be collected immediately after completion. The researcher, with the assistance of 20 trained research assistants, will distribute a total of 339 questionnaires to the respondents. The data collection exercise was conducted in a conducive premises to ensure ease of distribution and collection.

Presentation of Results

Analysis of Farmers’ Level of Awareness of Paid Agricultural Extension Services in Otukpo Local Government Area, Benue State.

Table 1 shows the level of farmers’ awareness of paid agricultural extension services.

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Table 1: Showing Farmers' Level of Awareness of Paid Agricultural Extension Services

S/N	Statement	SA	A	U	D	SD	$\bar{X}$	S.D.
1	Farmers are aware that agricultural extension services may require payment	90	130	50	40	14	3.3	0.92
2	Farmers have received information about paid extension services in Otukpo LGA	80	120	60	45	19	3.1	0.95
3	Farmers understand the benefits of paid agricultural extension services	75	125	65	35	24	3.0	0.98
4	Farmers are informed about different types of paid extension programs	70	130	70	40	14	3.0	0.92
5	Farmers have access to information on costs of agricultural extension services	65	125	75	40	19	2.9	0.96
6	Farmers know where to contact extension agents for paid services	75	120	70	35	24	3.0	0.97

Source: Field Survey, 2025.

Note: SA = Strongly Agree; A = Agree; U = Undecided; D = Disagree; SD = Strongly Disagree; $\bar{X}$ = Mean; S.D. = Standard Deviation.

From Table 1 above, on the farmers' level of awareness of paid agricultural extension services in Otukpo Local Government Area, majority of the respondents (220) demonstrated their acceptance of item one of the analysis indicating that farmers are aware that agricultural extension services may require payment. This was further validated by the mean score of 3.3, which is above the cutoff mean of 3.0, hence accepted. Similarly, in item two, a total of 200 respondents (combining "Strongly Agree" and "Agree") affirmed that farmers have received information about paid extension services in Otukpo LGA. This response was supported by a mean score of 3.1, which is above the cutoff mean of 3.0, thereby leading to its acceptance. For item three, 200 respondents agreed that farmers understand the benefits of paid agricultural extension services. This was further validated by the mean score of 3.0, which is equal to the cutoff mean of 3.0, hence accepted. Likewise, majority of the respondents (200) demonstrated their acceptance of item four of the analysis indicating that farmers are informed about different types of paid extension programs. This was further validated by the mean score of 3.0, which is equal to the cutoff mean of 3.0, hence accepted. Similarly, in item five, a total of 190 respondents agreed that farmers have access to information on costs of agricultural extension services. This response was supported by the mean score of 2.9, which is slightly below the cutoff mean of 3.0, hence rejected. Finally, majority of the respondents (195) demonstrated their acceptance of item six of the analysis indicating that farmers know where to contact extension agents for paid services. This was further validated by the mean score of 3.0, which is equal to the cutoff mean of 3.0, hence accepted.

Table 2 shows the analysis of farmers' attitude towards payment for agricultural extension services

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in Otukpo Local Government Area, Benue State.

Table 2: Showing Farmers' Attitude Towards Payment for Agricultural Extension Services

S/N	Statement	SA	A	U	D	SD	$\bar{X}$	S.D
1	Farmers feel that paying for extension services is beneficial	81	130	60	35	12	3.2	0.91
2	Farmers are willing to pay a small fee for quality extension services	75	125	70	35	13	3.1	0.93
3	Farmers believe that paid extension services improve farm productivity	70	135	65	40	8	3.1	0.89
4	Farmers think that free services are better than paid services	50	90	85	75	18	2.7	0.97
5	Farmers are concerned that paying for services may not guarantee results	55	105	75	60	13	2.9	0.94
6	Farmers would consider paying if benefits are clearly demonstrated	81	130	60	35	12	3.2	0.90

Source: Field Survey, 2025

As presented in Table 2 above, on the farmers' attitude towards payment for agricultural extension services in Otukpo Local Government Area, majority of the respondents (210) demonstrated their acceptance of item one of the analysis indicating that farmers feel that paying for extension services is beneficial. This was further validated by the mean score of 3.2, which is above the cutoff mean of 3.0, hence accepted. Similarly, in item two, a total of 200 respondents (combining "Strongly Agree" and "Agree") affirmed that farmers are willing to pay a small fee for quality extension services. This response was supported by a mean score of 3.1, which is above the cutoff mean of 3.0, thereby leading to its acceptance. For item three, 205 respondents agreed that farmers believe that paid extension services improve farm productivity. This was further validated by the mean score of 3.1, which is above the cutoff mean of 3.0, hence accepted. Likewise, majority of the respondents (140) demonstrated their acceptance of item four of the analysis indicating that farmers think that free services are better than paid services. This was further validated by the mean score of 2.7, which is below the cutoff mean of 3.0, hence rejected. Similarly, in item five, a total of 160 respondents agreed that farmers are concerned that paying for services may not guarantee results. This response was supported by the mean score of 2.9, which is below the cutoff mean of 3.0, thereby leading to its rejection. Finally, majority of the respondents (210) demonstrated their acceptance of item six of the analysis indicating that farmers would consider paying if benefits are clearly demonstrated. This was further validated by the mean score of 3.2, which is above the cutoff mean of 3.0, hence accepted.

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Hypotheses Testing

Hypothesis One

H_{01}: Farmers' level of awareness of paid agricultural extension services has no significant influence on their willingness to pay for agricultural extension services in Otukpo Local Government Area, Benue State

Table 3 shows simple linear regression analysis of the influence of farmers' awareness of paid agricultural extension services on willingness to pay

Table 3: Showing Simple Linear Regression Analysis of the Influence of Farmers' Awareness of Paid Agricultural Extension Services on Willingness to Pay

Model Summary

R	R Square (R^2)	Adjusted R Square	Std. Error of the Estimate
0.58	0.34	0.32	0.50

Analysis of Variance (ANOVA)

Source	Sum of Squares	df	Mean Square	F	Sig. (p-value)
Regression	13.77	1	13.77	55.08	.000
Residual	26.73	322	0.083		
Total	40.50	323			

Coefficients

Predictors	Unstandardized Coefficients (B)	Std. Error	Beta (β)	t	Sig. (p-value)
(Constant)	1.58	0.25		6.32	.000
Awareness of Paid Services	0.48	0.06	0.58	7.42	.000

Note: Dependent Variable (DV) = Paid Extension Services. Significant at $p < 0.05$. P < 0.05 DV - Paid Extension Services

From table 3, the model summary shows R value of 0.58, indicating that there is a moderate positive relationship between the awareness of paid agricultural extension services by farmers and their willingness to pay. The R2 value of 0.34 means that 34% of the variability in willingness to

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pay can be explained by awareness which is meaningful. The table for the analysis of variance (see below) has F(1, 322) = 55.08 with the p-value = 0.000, indicating that the model of ordinal regression is statistically significant. From the table of coefficients, it is evident that awareness has a significant relationship to willingness to pay (B = 0.48, These coefficients indicate that together with willingness to pay (B = 0.58), a linear combination of the models yields a different value; under the null hypothesis that there is no relationship between the variables, the mutual relationship between these two variables is statistically significant (t = 7.42, p < 0.05). Therefore, the null hypothesis (H02) is rejected, and it implies that the level of awareness of farmers has a significant effect on their willingness to pay for agricultural extension services in the Otukpo Local Governance Area (LGA).

Hypothesis Two

H_{o2}: Farmers' attitudes towards payment for agricultural extension services do not significantly affect their willingness to pay for such services in Otukpo Local Government Area, Benue State.

Table 4: Showing Simple Linear Regression Analysis of the Effect of Farmers' Attitudes on Willingness to Pay for Agricultural Extension Services

Model Summary

R	R Square (R^2)	Adjusted R Square	Std. Error of the Estimate
0.61	0.37	0.35	0.49

ANOVA

Source	Sum of Squares	df	Mean Square	F	Sig. (p-value)
Regression	14.97	1	14.97	62.4	0
Residual	25.53	322	0.079		
Total	40.5	323			

Coefficients

Predictors	Unstandardized Coefficients (B)	Std. Error	Beta (β)	t	Sig. (p-value)
(Constant)	1.5	0.23		6.52	0
Attitude towards Payment	0.5	0.06	0.61	7.9	0

Note. P < 0.05 DV - Paid Extension Services

From table 4 above, the model summary results R of 0.61, shows moderate positive relationship between attitude of farmers towards payment and willingness to pay for extension services in agriculture. The results from the ANOVA table is F (1,322) = 62.40 with p = 0.000, which means that the model of regression is statistically significant. From the coefficients table, one can see that attitude is a significant predictor of willingness to pay (B = 0.50, b = 0.61, t = 7.90, p < 0.05). Therefore, the null hypothesis (H_o2) is rejected and it suggests that the attitudes of the farmers towards payment have significant influence on their attitudes towards their willingness to pay for

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agricultural extension services in Otukpo LGA.

Discussion of Findings

The analysis of the awareness of the farmers for paid agricultural extension services showed a generally moderate level of awareness for all items. Farmers agreed that they knew that extension services may take payment (Mean = 3.3) and that there is information on paid services available in Otukpo LGA (Mean = 3.1). Respondents demonstrated a neutral to moderate level of understanding of the benefits of paid services (Mean = 3.0) and types of paid extension programs (Mean = 3.0). Awareness of the cost of service was slightly lower (Mean = 2.9) meaning there was a limited awareness of where to contact extension agents (Mean = 3.0). Overall, these mean values indicate that even though farmers have some knowledge about the availability of paid agricultural extension services, there are some gaps in their understanding of specific details such as costs and program types. The corresponding hypothesis (H_{02}) tested by simple linear regression showed also the existence of a moderate positive relationship between awareness and willingness to pay ($R = 0.58$, $R^2 = 0.34$, $p = 0.000$), which suggests a significant influence of awareness on farmer's willingness to pay for services. These findings are consistent with the work of Okeke and Ezeh (2021), who found that moderate level of awareness of extension services has a significant impact on the engagement of farmers in payment-based programs.

The analysis of farmers' attitudes towards payment for agricultural extension services revealed a general moderate positivity. Respondents agreed that payment for extension services is useful (Mean = 3.2) and they were moderately willing to pay a small fee for quality services (Mean = 3.1). They also felt that paid services have the potential for better farm productivity (Mean = 3.1), but also some skepticism was expressed about whether free services are better than paid services (Mean = 2.7) and whether payment guarantees result (Mean = 2.9). Importantly, farmers showed an openness of paying if the benefits are clearly demonstrated (Mean = 3.2). These mean values together indicate a moderately positive attitude and caution toward the quality and effectiveness of service. Hypothesis 2 (H02) which was tested with the help of simple-linear regression suggested a moderate positive relationship between attitude and willingness to pay ($R = 0.61$, $R^2 = 0.37$, $p = 0.000$), which shows that the attitude of farmers has a significant effect on their willingness to pay for agricultural extension services. These findings are in agreement with those of Obinna and Eze (2021), who found that positive attitudes towards the utility of services enhance the willingness of farmers to pay for extension services and Adamu and Okafor (2022), who found that farmers' perceptions on value and reliability influence their participation in paid extension services.

Conclusion

The results showed that most of the farmers were middle aged, mostly male and have secondary education. Awareness of paid agricultural extension services was moderate, and attitudes towards payment tended to be positive, but cautious with issues on quality of services and payment. The general results draw attention to the fact that although farmers are willing to pay for extension services, their choice is determined and affected by personal characteristics and perceptions of the value of services.

Recommendations

1. Extension service providers should tailor awareness campaigns to inform farmers about the benefits and value of paid agricultural extension services by using local languages and hands-

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on demonstrations to increase understanding.

2. Extension agencies should work on better service quality and transparency and show concrete results to build trust and confidence of farmers in paid services and provide timely support.
3. Training programs should be organized to improve decision-making and farm management skills in farmers to link the use of paid services with increased productivity and income to reinforce perceived benefits.

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Integration of Pragmatic Pedagogical Approaches in Basic Science and Technology Education Teaching among Post-Basic Schools in Nigeria: A Systematic Review

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Abstract

This paper examines the integration of pragmatic pedagogical approaches within the Basic Science and Technology (BST) curriculum under Nigeria's Universal Basic Education (UBE) framework. Grounded in John Dewey's philosophy of experimental pragmatism ("learning by doing"), the study addresses the systemic failure of traditional, teacher-centered rote instruction to cultivate functional scientific literacy and self-reliance among Nigerian youth. Through a conceptual analysis, this paper explores adaptable, student-centered strategies—including Project-Based Learning (PBL), Ethno-Scientific Contextualization, and Collaborative Inquiry Syndicates—proposing a structured curriculum matrix tailored to navigate large class sizes and severe resource constraints through low-cost instructional improvisation. The study analyzes critical structural barriers, such as infrastructural deficits, teacher professional inertia, and the constraints of terminal, exam-centric testing. Ultimately, the paper provides a holistic conceptual framework and offers actionable, multi-tiered policy recommendations for curriculum re-engineering, localized teacher up skilling, and assessment reforms necessary to foster a technologically proficient, inventive, and self-reliant generation.

Keywords: Pragmatic Pedagogical Approach, Basic Science and Technology Education, Teaching

Introduction

Education serves as the primary engine for sustainable national development, technological advancement, and economic self-reliance. Recognizing this imperative, the Federal Government of Nigeria, through the Nigerian Educational Research and Development Council (NERDC), restructured the basic education curriculum to establish the Basic Science and Technology (BST) theme under the 9-Year Universal Basic Education (UBE) programme. This integrated theme—comprising Basic Science, Basic Technology, Computer Studies (ICT), and Physical and Health Education—was intentionally designed to lay a solid foundation for scientific literacy, critical thinking, and inventive problem-solving from an early age. However, a severe disconnect persists between the progressive objectives stated in the National Policy on Education and the instructional realities of the average Nigerian classroom. Driven by institutional pressures to cover dense syllabi ahead of high-stakes standardized examinations, instruction remains overwhelmingly dominated by what Paulo Freire termed the "banking concept" of education. Teachers default to passive, lecture-style dictation, treating knowledge as an abstract, static commodity. Science laboratories, where they exist, are frequently non-functional or treated as restricted demonstration zones rather than active spaces for hands-on exploration. Consequently, students view science and technology as alien, theoretical frameworks detached from their lived socio-cultural and economic realities. To bridge this chasm, a profound paradigm shift toward pragmatic pedagogies is essential. Rooted in the philosophical traditions of Charles Sanders Peirce, William James, and John Dewey, pragmatism asserts that the validity and value of knowledge reside entirely in its practical application and utility.

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When operationalized within the BST framework, pragmatic pedagogy transforms the classroom from a site of passive reception into an active laboratory of discovery, where learning is an iterative, transactional process between the student and their immediate environment. This paper provides a comprehensive conceptual examination of pragmatic pedagogical approaches within Nigerian basic education. By analyzing localized instructional strategies, designing an adaptable curriculum matrix, and addressing systemic institutional barriers, this study outlines a clear pathway toward a functional, experiential, and self-reliant model of science and technology education in Nigeria.

Literature Review

The discourse surrounding the effectiveness of Basic Science and Technology (BST) instruction in Nigeria has gained significant traction among indigenous scholars, particularly concerning the persistent failure of traditional instructional methods. This section evaluates the current literature across three primary thematic areas: the crisis of pedagogical delivery in Nigeria, the concept of strategic instructional improvisation, and the integration of ethno-science within the school curriculum.

The Crisis of Pedagogical Delivery in Nigerian BST Education

Numerous Nigerian scholars have documented the systemic limitations of the traditional lecture method—often referred to as the "talk-and-chalk" approach. Okebukola (2020) argues that science instruction in Nigerian secondary schools remains fundamentally moribund due to its over-reliance on rote memorisation. This method treats science as an absolute, immutable body of facts rather than an active process of inquiry. Furthermore, research by Jegede (2017) highlights the "cognitive dissonance" experienced by Nigerian learners when abstract scientific laws are taught without physical contexts or tactile experimentation. In a highly crowded classroom environment, typical of urban public schools in states like Lagos and Kano, the teacher's role defaults to an authoritarian information provider, rendering students passive observers in their own educational journey.

Strategic Instructional Improvisation in Resource-Constrained Environments

Given the chronic underfunding of public education, the absence of standard laboratory apparatus (such as glass beakers, indicators, and test tubes) is a defining feature of the Nigerian educational landscape. To counter this bottleneck, the concept of Instructional Improvisation has emerged as a central focus within indigenous educational research. Onoja (2019) defines improvisation as the deliberate sourcing, design, and deployment of local, low-cost, or upcycled materials from the immediate environment to replicate standard educational equipment. Scholars such as Bichi (2021) have demonstrated empirically that students taught using improvised materials often perform as well as, or better than, peers taught using conventional laboratory equipment. This is because the act of sourcing and building improvised tools forces students into an active, hands-on relationship with scientific principles. Pragmatically, improvisation is not merely a desperate stopgap for poverty; it is an active pedagogical strategy that demystifies science by stripping it of its foreign, industrial mystique and grounding it in everyday household materials.

Ethno-Science and Indigenous Knowledge Systems (IKS)

A critical sub-theme in contemporary Nigerian science education is Ethno-science—the study of scientific ideas from the perspective of local cultures. Historically, Western-style schooling in Africa severed the connection between school science and community practices. Eshiet (2018) points out that traditional Nigerian societies possess highly sophisticated, functional scientific knowledge, ranging from food preservation (smoking fish, fermenting cassava) to chemical processing (local soap making, palm oil extraction) and metallurgy. When teachers consciously integrate these indigenous knowledge systems into the BST curriculum, they bridge the cultural alienation often felt by African

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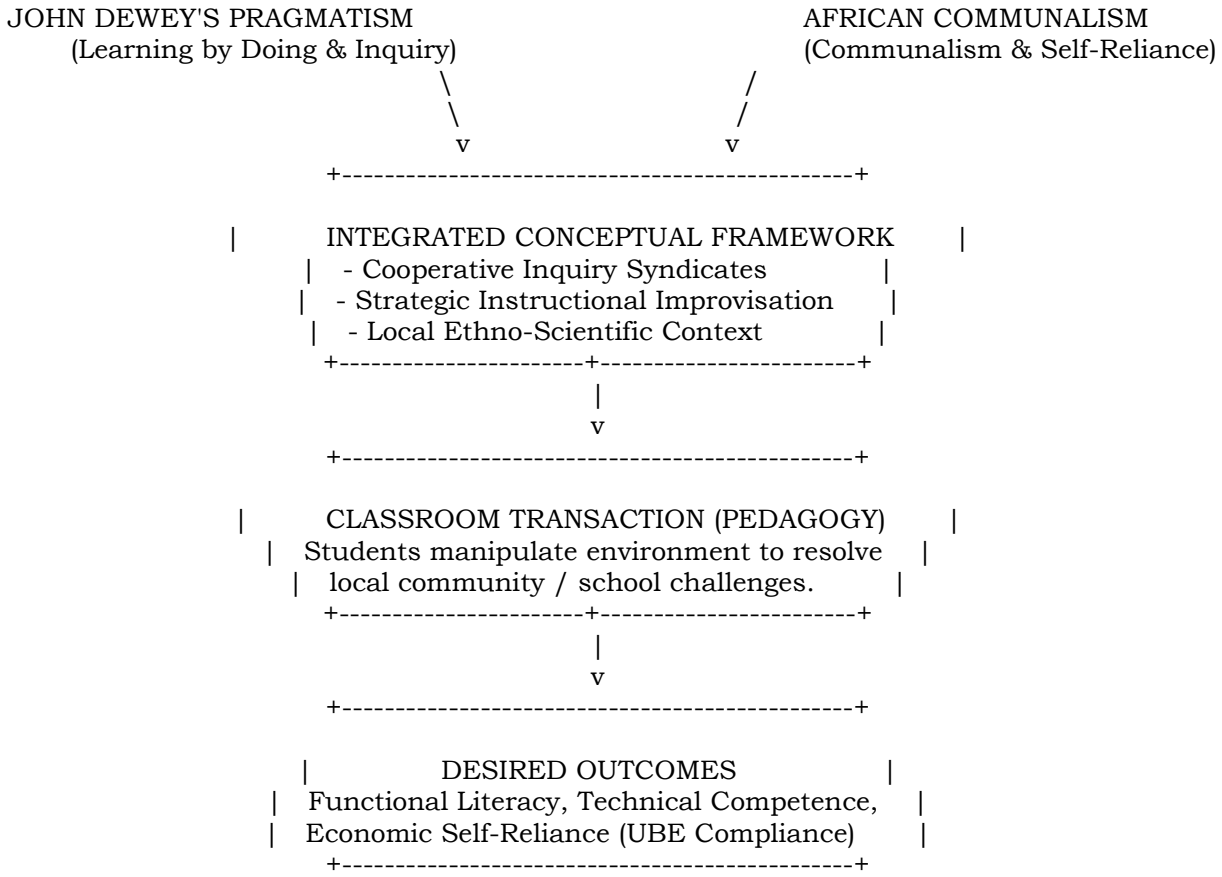
children. By utilizing local socio-industrial processes as primary teaching aids, the educator validates the student's prior cultural experiences, creating a smoother cognitive transition into formal scientific reasoning.

Conceptual Framework

Philosophical Alignment: Mapping Dewey onto African Communalism

The conceptual framework of this study synthesizes John Dewey's *Transactional Theory of Learning* with the socio-cultural principles of *African Communalism* (often articulated through the concept of *Ubuntu* or *Omoluwabi*). Dewey's pragmatism posits that learning is not a passive internal cognitive state, but an active, transactional process between the organism (the student) and their environment. Knowledge is a tool generated to resolve a felt disruption or problem in that environment.

In the African context, this transactional relationship is naturally collective rather than individualistic. Traditional African education was inherently pragmatic and communal; children learned agriculture, medicine, and engineering by actively participating in the daily socioeconomic life of the community alongside adult mentors.



Operational Framework Components

This framework models how these two philosophies intersect to dictate instructional delivery within the Nigerian Universal Basic Education (UBE) system:

1. The Experiential Stimulus (The Localized Problem): The pedagogical process begins with a real, observable problem within the school or local community (poor drainage, waste accumulation, crop pests). This acts as the disruptive trigger that initiates reflective thought.

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2. The Cooperative Inquiry Syndicate: To navigate large class sizes, students are organized into collective units that mirror traditional communal work groups. Learning becomes a social dialogue where students debate, share tasks, and collaborate on solutions.
3. The Transactional Manipulation (Improvisation): Students actively alter their environment by sourcing local waste or natural materials to construct functional, physical prototypes (artifacts).
4. The Evaluation of Utility (Authentic Assessment): In strict alignment with pragmatic philosophy, the project is judged not on its ability to match a textbook definition, but on its functional utility—does the filter clarify the water? Does the mechanical pulley reduce the effort needed to lift the load?

By blending Deweyan transaction with local communal structures, this framework provides a culturally responsive, highly practical roadmap for transforming the teaching of Basic Science and Technology in Nigeria. The article further maps out a full sample curriculum matrix showing how other BST topics (like ICT/Computer Studies or Health Education) can be translated into these project-based rubrics

Standards-Based Scoring Rubric

To remove teacher bias and ensure fairness, grading must rely on a structured rubric distributed to students before the project begins.

Sample Authentic Assessment Rubric (Total: 20 Marks)

Assessment Criteria	Unacceptable (1-2 Marks)	Proficient (3-4 Marks)	Exemplary (5 Marks)
Scientific & Tech Reasoning	Model shows no understanding of forces or material properties.	Model shows basic understanding; design functions but has structural weaknesses.	Model perfectly applies concepts of stability, strength, and material properties.
Use of Local Materials	Used expensive, store-bought materials; no resourcefulness.	Used some local materials, but relied heavily on ready-made items.	Exceptional improvisation; 100% sourced from free, local, or recycled waste materials.
Functionality & Design	The prototype collapses or fails to channel water/withstand force.	The prototype holds up but requires manual assistance to function fully.	The prototype is stable, durable, and fully functional under simulated conditions.
Teamwork & Presentation	One or two students did all the work; group cannot explain their design.	Most members contributed; presentation is clear but lacks technical depth.	Equal participation; group confidently defends their technical choices during the viva.

Integrating PBL with Large Class Realities in Nigeria

To make project-based assessment realistic in an average public school with 80+ students per class:

1. Group Structuring: Divide the class into large syndicates of 10 students. Assign specific operational roles within each group (e.g., 1 Project Manager, 2 Material Sorters, 3 Builders, 2 Documentation Officers, 2 Presenters). This ensures individual accountability and prevents the teacher from grading 80 individual projects.
2. Progressive Milestones: Do not grade everything at the end. Break the 20-mark assessment down across the term: 5 marks for the initial sketch/plan (Week 4), 10 marks for the physical prototype build (Week 8), and 5 marks for the final group defense (Week 10).

The table below maps out a comprehensive Pragmatic Curriculum Matrix for Basic Science and Technology (BST) at the Nigerian Junior Secondary School (JSS) level. This matrix is explicitly

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designed to function within the Universal Basic Education (UBE) framework, replacing abstract theories with localized, low-cost projects that address large class realities through group syndicates.

Pragmatic Curriculum Matrix for JSS Basic Science and Technology

BST Sub-Theme & Class	Curriculum Topic (NERDC Standard)	The Pragmatic Problem Prompt (Local Context)	Group Project Deliverable (The Artifact)	Low-Cost / Improvisation Materials Sourced Locally	Authentic Assessment Focus (PBL Rubric Allocation)
Basic Science *(JSS 1)*	Environmental Pollution *(Air, Water, Land)*	"Our community dump site is burning open waste, polluting the air and local water channels. How can we clean or reuse this water?"	A functional, layered water filtration column and an awareness poster on the dangers of open burning.	Plastic bottles, charcoal from kitchen stoves, clean sand, gravel, cotton cloth.	5M: Filter Design 10M: Water Clarity/Utility 5M: Team Presentation *(Total: 20 Marks)*
Basic Technology *(JSS 1)*	Woodwork / Hand Tools *(Properties & Uses)*	"The school desks are falling apart because the nails are loose and the wood joints are failing. How can we fix them?"	A small, functional wooden storage crate or bench model using strong, local geometric joints.	Scrap timber from local sawmills, discarded nails, handsaws, local gum (*Ache*).	5M: Joint Accuracy 10M: Structural Strength 5M: Safety Adherence *(Total: 20 Marks)*
Computer Studies (ICT) *(JSS 2)*	The Internet & Search Engines *(Information Retrieval)*	"Local farmers in our area are losing crops to pests because they do not know the latest chemical-free remedies."	A printed or handwritten "Local Farmer's Info-Brochure" compiled by extracting data via internet search strategies.	Shared mobile phone/tablet, cybercafé access, used printing sheets or cardboard.	5M: Search Query Logic 10M: Relevance of Data 5M: Formatting/Layout *(Total: 20 Marks)*
Physical & Health Ed. *(JSS 2)*	Community Health & Sanitation *(Disease Vector Control)*	"Malaria and typhoid cases peak in our neighborhood during the rainy season due to stagnant puddles and poor drainage."	A physical map of the school community highlighting vector breeding grounds, plus a 10-day drainage	Cardboard sheets, colored markers/pencils, community waste charts.	5M: Breeding Ground Mapping 10M: Execution of Action Plan 5M: Peer Review *(Total: 20 Marks)*

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			clearance action log.		
Basic Science *(JSS 3)*	Electrical Energy & Circuits *(Series & Parallel Circuits)*	"Frequent power outages hit our classrooms during evening study prep. How can we build an emergency lighting backup system?"	A working parallel-circuit lighting model using small bulbs that can stay lit even if one bulb fails.	Used torchlight batteries, scrap electrical wires from mechanics, small LEDs, cardboard box.	5M: Circuit Diagram Proof 10M: System Functionality 5M: Technical Defense *(Total: 20 Marks)*
Basic Technology *(JSS 3)*	Mechanical Engineering Motion *(Gears & Pulleys)*	"Deep-well water retrieval in our community requires intense physical strength, causing muscle strain for children."	A functional, scale-model mechanical pulley or windlass system capable of lifting weights with minimal effort.	Used thread spools, coat hanger wires, strong twine, small plastic buckets, wood blocks.	5M: Mechanical Advantage Calc. 10M: Load-Bearing Capacity 5M: Material Innovation *(Total: 20 Marks)*

Implementation Guidelines for the Matrix

To seamlessly integrate this matrix into a term-long Nigerian academic schedule without overwhelming teachers, use the following operational structure:

1. Week 1–2 (Contextual Lectures): Teach the core scientific or technological laws using local examples. Introduce the project prompt early so groups can begin brainstorming.
2. Week 3–4 (Design and Material Sourcing): Groups submit a rough sketch or structural plan of their artifact for approval. Students spend this time gathering free, local, or upcycled materials.
3. Week 5–7 (The In-Class Build): Dedicate two standard practical periods to let groups construct their prototypes in class. This allows the teacher to monitor individual contributions and guide group collaboration.
4. Week 8–9 (The Defense / Exhibition): Instead of a standard test, organize a "Science and Tech Exhibition Day" in the school courtyard. Groups present their models, and the teacher grades their technical performance on the spot using the predefined rubric.

Discussion: The Socio-Economic Imperative of Pragmatic Pedagogy

The conceptual arguments presented in this paper underscore an urgent reality: Nigeria's aspiration for technological advancement and economic self-reliance, as outlined in the Vision 2030 agendas and the National Policy on Education, cannot be achieved through passive pedagogical frameworks. The traditional reliance on rote memorisation and abstract instruction has created a systemic paradox—producing graduates who hold certificates in science and technology but lack the functional capacity to troubleshoot local technical problems, innovate industrial processes, or drive independent entrepreneurship. By repositioning the Basic Science and Technology (BST) curriculum

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within John Dewey's pragmatic philosophy, education is transformed into a direct catalyst for national development. When a junior secondary school student builds a functional water filtration column from charcoal and sand, or constructs a parallel circuit using upcycled mechanics' wire, they are not merely memorising facts for an examination; they are mastering the foundational processes of industrial engineering, resource optimization, and environmental management. Furthermore, the integration of strategic instructional improvisation and ethno-science directly dismantles the colonial-era misconception that science is an imported, unattainable Western construct. Grounding chemistry, physics, and technology in local practices like palm oil extraction or mud-hut architecture validates the learner's socio-cultural environment. This cultural validation fosters an innovative mindset, encouraging students to view their immediate communities not as landscapes of lack, but as active laboratories ripe for scientific intervention and sustainable development.

Overcoming the Crux of Large Class Realities

Critics of student-centered, pragmatic approaches in developing nations often cite the logistical impossibility of managing project-based learning within classrooms containing 80 to 100 students. This paper explicitly counters that critique through the structural introduction of Cooperative Inquiry Syndicates. By organizing large classrooms into structured, self-governing student teams modeled after traditional African communal work groups, the teacher's role shifts from an overwhelmed disciplinarian to a high-level strategic facilitator. Instead of grading 100 individual assignments, the educator evaluates 10 collective, multi-dimensional projects. This collective approach distributes the logistical burden of sourcing materials among the students, builds critical soft skills—such as peer accountability, conflict resolution, and technical division of labor—and ensures that underfunded schools can deliver high-quality, practical STEM experiences with zero capital expenditure.

Concluding Synthesis

The current structural stagnation within Nigerian BST classrooms is not a failure of curriculum design, but a failure of pedagogical and assessment alignment. The NERDC curriculum possesses progressive, application-oriented goals on paper, but the institutional mechanics of the Universal Basic Education (UBE) system continue to reward the passive replication of text. To break this cycle, Nigeria must boldly operationalise a pragmatic educational framework. This requires moving beyond temporary teacher workshops and adopting a systemic approach that links teacher promotions to instructional improvisation, anchors 40% of basic school grading metrics to physical project artifacts, and transforms the local community into an active extension of the science classroom. Ultimately, pragmatism offers more than just a teaching method for resource-scarce environments; it offers a liberating philosophy of education. By shifting the pedagogical focus from "what to think" to "how to do," Nigeria can cultivate a new generation of scientifically literate, critically thinking, and technologically resourceful citizens capable of inventing local solutions to national challenges.

Formal Policy Recommendations

To systematically institutionalize pragmatic pedagogies within the Nigerian Basic Education ecosystem, a coordinated, multi-tiered intervention is required from federal, state, and local educational authorities. The following actionable policy recommendations are proposed:

1. Re-Engineer the National Assessment Architecture (NERDC & NECO): The Nigerian Educational Research and Development Council (NERDC) and the National Examination Council (NECO) must reform the Basic Education Certificate Examination (BECE) guidelines to mandate that 40% of the Continuous Assessment (CA) score be derived strictly from standardized, group-based Project-Based Learning (PBL) artifacts. Create standardized regional portfolio moderation panels to audit

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school project rubrics, ensuring that terminal written examinations are balanced by verified, practical student creations.

2. Standardize "Improvisation Lab" Protocols in Teacher Upskilling (UBEC & SUBEBs): The Universal Basic Education Commission (UBEC), in partnership with State Universal Basic Education Boards (SUBEBs), must transition all in-service training to an "Improvisation Lab" format. Teachers must be trained on how to use free, locally sourced, and upcycled materials to deliver complex BST lessons. This training should explicitly focus on methods for dividing large, crowded classes (80+ students) into structured cooperative learning syndicates.
3. Reform Pre-Service Teacher Curricula (NCCE & NUC); The National Commission for Colleges of Education (NCCE) and the National Universities Commission (NUC) must overhaul the teacher education curriculum for BST disciplines. Introduce mandatory coursework in *Ethno-Science, Instructional Improvisation,* and *Constructivist Facilitation Techniques*. Graduation requirements for pre-service teachers must include a teaching practice portfolio that demonstrates the successful execution of student-centered, project-based inquiry.
4. Link License Renewal and Career Advancement to Pragmatic CPD Credits (TRCN); The Teachers Registration Council of Nigeria (TRCN) should mandate that a specific percentage of Continuous Professional Development (CPD) credits required for license renewal be earned through verified courses in practical, experiential pedagogy. In tandem, state civil service commissions should make the defense of an original, localized instructional improvisation model a core requirement for promotion across teaching cadres.
5. Establish Community-School Technology Clusters (LGEAs): Local Government Education Authorities (LGEAs) must broker strategic partnerships between public schools and local vocational networks. Establish protocols where JSS students can conduct structured field studies and project builds within local automobile mechanic workshops, carpentry sheds, and agricultural hubs. This turns the immediate community into an active, low-cost extension of the school's science laboratory.

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Correlation Between Integration of Artificial Intelligence-Assisted Instruction and Self-Efficacy in Biology Teaching and Learning among Secondary School Students in Gusau, Zamfara State

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Abstract

This study investigated Correlation between integration of Artificial Intelligence (AI)-assisted instruction and Biology students' self-efficacy among on secondary schools in Gusau metropolis, Zamfara State. The population comprised all private senior secondary school biology students in the study area who utilize AI tools for academic purposes. A sample of 313 students was selected using a purposive sampling technique. The study was guided by two research objectives, two research questions, and two null hypotheses. A descriptive survey research design was adopted for the study. Data was collected using an instrument titled "Biology Students AI and Self-Efficacy Questionnaire" (BSASEQ). The instrument was validated by experts and pilot-tested, yielding a reliability coefficient of 0.75. The research questions were analyzed using descriptive statistics (Mean and Standard Deviation), and the null hypotheses were tested at the 0.05 level of significance using Pearson Product-Moment Correlation Coefficient and an independent samples t-test. The findings revealed that variations in AI usage do not correspond with changes in students' self-efficacy levels in biology and no significant gender differences in self-efficacy were found. The study recommends that comprehensive AI literacy courses describing the functional mechanics, ethics, and practical applications of AI should be integrated into educational institutions to optimize technological adoption.

Keywords: Artificial Intelligence, AI-Assisted Instruction, Self-Efficacy, Secondary Education.

Introduction

Artificial Intelligence (AI) has the capacity to improve student engagement and comprehension by automating administrative activities, personalizing learning experiences, and providing real-time feedback (Holmes et al., 2019). When AI is integrated into education, individual variances can be accommodated. AI is especially helpful in addressing individual learning demands and encouraging self-directed learning in secondary education settings (Zawacki-Richter et al., 2019), allowing students to learn at their own pace. Students can experience individualized, engaging, and immersive learning through AI-based solutions, including virtual labs, AI-assisted tutoring, and interactive simulations (Chen et al., 2018). To ensure that future citizens can not only utilize AI technologies but also interact with them critically, ethically, and artistically, international organizations like UNESCO and the World Economic Forum have urged the integration of AI capabilities into national curricula (Milberg, 2024; UNESCO, 2023b). These advancements show that AI literacy—the capacity to recognize, comprehend, assess, and ethically use AI technologies—is emerging as a crucial 21st-century talent and a primary educational priority (Hossain, 2025a; Voulgari et al., 2022).

AI literacy goes beyond basic technological expertise to include ethical and cognitive aspects, such as contextual awareness, data integrity, transparency, and responsible use (UNESCO, 2023a;

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Voulgari et al., 2022). In the context of algorithmic systems and machine-generated content, AI literacy can be seen as an advancement of well-established information literacy paradigms, extending conventional abilities of finding, assessing, and using information ethically. More academics contend that fostering such literacy encourages critical agency, optimism about AI's role in society, and technology fluency (Hollands & Breazeal, 2024). A rising number of international organizations have advocated for the inclusion of AI literacy skills in national curricula. This aligns with the World Economic Forum's recommendation to integrate AI into education to produce workers who can interact critically with new technology (Milberg, 2024). In a similar vein, the Organization for Economic Co-operation and Development (OECD, 2025) intends to incorporate Media and Artificial Intelligence Literacy (MAIL) into the Program for International Student Assessment (PISA), indicating a rising global acknowledgement of AI competency. Recent studies highlight the necessity of integrating AI literacy into educational settings. According to Hornberger et al. (2023) and Milberg (2024), students expect AI to be a major part of their future employment, even though many of them already use AI technologies daily. According to Williams (2024), AI literacy is a fundamental ability at all educational levels. In line with this, Hossain (2025a) encourages students to interact critically, morally, and responsibly with AI technology by promoting the development of critical AI literacy and AI citizenship. Studies have also shown that teachers' preparedness and skills play a major role in how well AI is integrated into classrooms. Teachers must acquire AI competencies to promote 21st-century skills and provide an example of appropriate AI engagement (Khazanchi & Khazanchi, 2025; Hossain et al., 2024). Consequently, teacher training programs need to be reviewed to accommodate AI. According to Su et al. (2023), there are substantial gaps in instructors' understanding of AI, curriculum design constraints, and a lack of pedagogical standards. Many instructors lack the conceptual knowledge required to teach with or about AI. These results highlight the need for institutional support and professional development to enable instructors to facilitate AI literacy. The advancement of AI instruction in education has transformed the way students interact with technological tools, creating distinct psychological dimensions related to technology reliance, adaptivity, and self-efficacy. Self-efficacy refers to one's confidence in their ability to use AI tools effectively (Morales-Garcia et al., 2025). This variable can influence technological dependence, thereby affecting the academic performance and emotional well-being of students.

Self-efficacy, defined broadly as the belief in one's ability to organize and execute actions necessary to achieve specific goals (Bandura, 1997), is a key concept in adapting to new technologies. In educational settings, a high degree of technological self-efficacy allows individuals to complete assignments using technology with greater fulfillment (Yang et al., 2025). Conversely, students with lower self-efficacy may become agitated when encountering difficult tasks, choosing evasion over completion (Bandura, 2010). Self-efficacy is shaped by external elements, including feedback, rewards, communication, and motivation (Peechapol et al., 2018). Generative AI tools capable of creating content, such as text, images, or code (e.g., ChatGPT and DeepSeek) can interact with individuals via voice or text in a human-like manner, potentially enhancing communication, engagement, and learning experiences (Labadze et al., 2023). In Biology education, students' psychological states affect how confidently they face academic challenges and apply biological concepts in their daily lives. While high self-efficacy fosters adaptability, low confidence can inhibit learning quality and conceptual application. Studies have shown that AI instruction can significantly modulate psychological impacts on learners. For instance, a study by Huang et al. (2024) highlighted that learners' acceptance of AI positively influences their well-being and confidence. Similarly, Nabila and Amrullah (2025) indicated that AI instructional tools contribute significantly to student

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efficiency, improved academic performance, elevated self-efficacy, and enhanced learning engagement. Researchers like Zhang and Aslan (2021) emphasize the importance of understanding student-centered viewpoints to create AI tools that align with students' cognitive capacities. While research by Yaseen et al. (2025) indicates that AI tools support autonomous learning by providing tailored feedback, empirical data on how well these tools cultivate independent confidence remains limited. Three main approaches, learning from AI, learning about AI, and learning with AI were identified in a study looking at the integration of AI in K–12 schools, which noted that interrelated institutional barriers often impede progress, requiring customized school strategies (Wang & Cheng, 2021). Najmuddeen et al. (2024) investigated the impact of AI-based learning systems on biology education among students in Zaria, Kaduna State, utilizing a sample of 150 teachers and students. Data gathered via a Likert-scale questionnaire revealed that AI integration significantly enhances academic performance, conceptual retention, and student motivation compared to traditional methods. Statistical analysis showed mean scores consistently exceeding the evaluation threshold, with significant p-values across the hypotheses. Consequently, the study recommended that educators adopt AI tools to foster higher engagement and identify at-risk students for early interventions. Naeem et al. (2024) conducted a systematic study of 74 records to investigate the transformative impact of AI on secondary biology education, focusing on instruction, assessment, and administration. The research highlighted how AI interventions, such as personalized learning and simulators, address complex biological topics like genetics and cell biology. The study identified that AI significantly enhances learner outcomes and provides educators with efficient tools for performance assessment, offering a framework for policymakers to navigate AI integration challenges.

A study by Duy et al. (2025) explored AI integration in biology self-learning among high school students, revealing departures from the traditional Technology Acceptance Model (TAM). While students perceived AI as useful, this did not automatically translate into a strong behavioral intention to use it for advanced tasks. Instead, students primarily utilized AI for exam preparation and homework rather than complex experimental simulations, citing concerns over data accuracy, privacy, and limited virtual laboratory capabilities. The findings suggest that to move beyond basic chatbot interactions, educational institutions must prioritize specialized AI tools alongside comprehensive AI literacy programs. Benjamin et al. (2025) investigated the efficacy of the Technology-Education-Art (TEA) application in enhancing visual literacy among 85 biology students in Lagos, Nigeria, a group historically noted for struggling with the visual demands of the discipline. Quantitative analysis through Analysis of Covariance (ANCOVA) revealed no statistically significant shift in overall student attitudes toward biological sketching, but qualitative feedback indicated that students perceived the tool as highly effective. The study recommended that educational authorities prioritize technological integration as a supportive pedagogical resource rather than a threat to traditional instruction. Afolasade and Nyong (2018) investigated biology students' visual literacy skills and their effects on learning. According to their survey, 86.7% of pupils scored below 50% on the Visual Literacy Scale, indicating poor visual literacy baseline skills. The authors stressed that biology is fundamentally visual, relying on imagery to explain living systems. This emphasizes the need for creative methods to improve students' capacity to comprehend and produce biological drawings. According to the United Nations Educational, Scientific, and Cultural Organization's Beijing Consensus on Artificial Intelligence and Education (UNESCO, 2019), AI has the potential to revolutionize teaching, address major educational challenges, and hasten the achievement of the Sustainable Development Goals (SDGs). However, educational innovation faces structural

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constraints due to the historically measured pace of technology adaptation across Sub-Saharan Africa (African Union, 2023). This project investigates the interface of AI technologies and student psychological outcomes within the local educational context to address these gaps.

Statement of the Problem

Senior secondary biology is often perceived as a difficult subject due to its voluminous content and abstract concepts, leading to significant challenges among students. This often manifests as a lack of confidence, fear of failure, and avoidance of scientific inquiry, which ultimately hinders academic performance and suppresses domain self-efficacy. While many students in senior secondary schools have begun utilizing AI-assisted tools, such as intelligent tutors and generative AI to navigate these challenges, there is a dearth of empirical data on how this usage correlates with their academic self-belief. It remains unclear whether the anytime, anywhere nature of AI truly acts as a cognitive buffer that enhances self-efficacy, or if it creates a digital dependency that masks underlying conceptual difficulties. Furthermore, it is yet to be determined if the impact of these AI tools on biology self-efficacy is uniform across both male and female students. If this gap in knowledge persists, educators may continue to implement AI tools without understanding their role in student academic confidence and technological mastery. Therefore, this study seeks to investigate the relationship between the use of AI-assisted instruction and biology students' self-efficacy among senior secondary schools, while also examining the moderating role of gender.

Research Objectives

The objectives of the study were:

1. To determine the relationship between the use of AI-assisted instructional tools and the level of biology self-efficacy among senior secondary students.
2. To compare the biology self-efficacy levels of male and female students who utilize AI tools for learning.

Research Questions

The following research questions guided the study:

1. What is the relationship between students' use of AI-assisted biology instruction and their levels of biology self-efficacy?
2. Is there a significant difference in biology self-efficacy levels between male and female students who use AI-assisted tools?

Research Hypotheses

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

Ho_1. There is no significant relationship between the use of AI-assisted instructional tools and senior secondary students' biology self-efficacy.

Ho_2. There is no significant difference in the mean biology self-efficacy scores of male and female students who utilize AI-assisted instruction.

Research Methodology

The study employed a descriptive survey research design. The population consisted of all private senior secondary school (SSS) biology students in Gusau metropolis, Zamfara State, who utilized AI tools (such as Gemini, ChatGPT, or specialized biology learning apps) for their academic work. A sample size of 313 students was selected using a purposive sampling technique to ensure the inclusion of only those students who confirmed active use of AI tools for biology learning. The instrument, titled "Biology Students AI and Self-Efficacy Questionnaire" (BSASEQ), was developed by the researchers for data collection. The instrument was validated by measurement and evaluation experts and was pilot-tested on a cohort outside the final sample. The data from the pilot test was

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analyzed using Cronbach's alpha, establishing a reliability coefficient of 0.75. Data analysis was executed using descriptive statistics (Mean and Standard Deviation) for the research questions, while the null hypotheses were analyzed using the Pearson Product-Moment Correlation Coefficient and an independent samples t-test.

Presentation of Results

Research Question One

What is the relationship between students' use of AI-assisted biology instruction and their levels of biology self-efficacy?

Table 1: Students' Use of AI-Assisted Biology Instruction and Biology Self-Efficacy Levels

Variable	N	Mean	SD	Mean Difference
AI Usage	313	2.16	0.47	1.04
Self-Efficacy	313	3.20	0.42	

Source: Fieldwork, 2026

Table 1 displays the descriptive summary of students' use of AI-assisted biology instruction and their corresponding biology self-efficacy. AI usage obtained a mean score of 2.16 (SD=0.47), while biology self-efficacy obtained a mean score of 3.20 (SD=0.42), resulting in a mean difference of 1.04. This descriptive baseline suggests that students reported a relatively high confidence level in their biology capability while practicing moderate or infrequent utilization of AI tools.

Research Question Two

Is there a significant difference in biology self-efficacy levels between male and female students who use AI-assisted tools?

Table 2: Biology Self-Efficacy Levels Between Male and Female Students

Variable	Gender	N	Mean	SD	Mean Difference
Self-Efficacy	Male	157	3.20	0.36	0.01
	Female	156	3.19	0.47	

Source: Fieldwork, 2026

Table 2 shows the comparative self-efficacy levels between male and female students who utilize AI-assisted tools. The data indicates that male students recorded a mean self-efficacy score of 3.20 (SD=0.36), while female students recorded a mean score of 3.19 (SD=0.47). The resulting mean difference of 0.01 indicates that both groups exhibit highly similar descriptive levels of academic self-belief. However, the higher standard deviation within the female cohort indicates a slightly wider variance in self-efficacy distribution compared to their male peers.

Analysis of the Null Hypotheses

Hypothesis One: There is no significant relationship between the use of AI-assisted instructional tools and senior secondary students' biology self-efficacy.

Table 3: Pearson Product-Moment Correlation between AI Tool Usage and Biology Self-Efficacy

Variable	N	Mean	SD	df	Correlation (r)	p-value	Decision
AI Usage	313	2.16	0.47	311	.383	.888	Retained
Self-Efficacy	313	3.19	0'42				

Source: Fieldwork, 2026

Table 3 presents the correlation analysis between AI-assisted instructional tool usage and biology self-efficacy among the sampled students. The analysis revealed a Pearson correlation coefficient of 0.383 with an associated p-value of 0.888. Because the calculated p-value (0.888) is substantially greater than the designated 0.05 significance level, the null hypothesis is retained. This implies that there is no statistically significant relationship between the frequency of AI tool usage and the levels of biology self-efficacy experienced by the students.

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Hypothesis Two: There is no significant difference in the mean biology self-efficacy scores of male and female students who utilize AI-assisted instruction.

Table 4: Independent Samples t-test of Biology Self-Efficacy Scores by Gender

Gender	N	Mean	SD	t-value	p-value	Df	Decision
Male	157	3.20	0.47	0.194	.847	311	Retained
Female	156	3.19	0.36				

Source: Fieldwork, 2026

Table 4 indicates that male students reported a mean self-efficacy score of 3.20 (SD=0.47), while female students reported a mean self-efficacy score of 3.19 (SD=0.36). The inferential analysis shows that this minor variation was not statistically significant, t value=0.194, p=0.847. Consequently, the second null hypothesis is retained, demonstrating that gender does not exert a significant moderating impact on the academic self-efficacy levels of the participants.

Discussion of the Findings

According to literature on AI literacy (Chai et al., 2021), students frequently maintain fixed perceptions of their academic abilities when digital instructional tools are treated as optional or peripheral rather than fully integrated elements. This aligns with the baseline descriptive observation in Table 1, where solid self-efficacy profiles co-occurred alongside lower, non-systematic tool utilization. Concurrently, Ocaña-Fernández et al. (2019) observed that when modern digital platforms are smoothly integrated directly within structural curricula, contemporary students leverage them naturally without fundamentally altering their pre-existing confidence baselines. This indicates that core self-efficacy traits may be driven by fundamental classroom interactions rather than the digital tools themselves. Furthermore, the absence of significant gender differences in technology-mediated self-efficacy corroborates the findings of Recber et al. (2018), who noted minimal gender discrepancies within structured digital learning spaces, though it diverges from patterns observed by Vekli (2021).

The non-significant correlation between AI integration and biology self-efficacy (r=0.383, p>0.05) conceptually supports the core tenets of the Technological Pedagogical Content Knowledge (TPACK) framework (Koehler & Mishra, 2009). This structural framework implies that introducing a technical medium as a general instructional aid does not automatically elevate or alter a learner's fundamental academic self-concept toward the subject matter. These findings further corroborate the assertions of Oloyede et al. (2022) within the West African secondary school environment, which demonstrated that subject-specific student confidence is predominantly dictated by immediate environmental variables—such as historical teacher-student relationships, continuous assessment feedback, and extensive curriculum volume—rather than the specific technological channel utilized for lesson delivery. The findings fail to support the optimistic predictions of Luckin (2018), who argued that customized, AI-driven personalized feedback loops should noticeably elevate student confidence levels by providing rapid, nonjudgmental mastery support. The findins also disagree with Huang et al. (2024) who highlighted that learners' acceptance of AI positively influences their well-being and confidence and Nabila and Amrullah (2025) who indicated that AI instructional tools contribute significantly to student efficiency, improved academic performance, elevated self-efficacy, and enhanced learning engagement. The absence of a significant statistical link in this study indicates that AI tools currently act as neither an acute booster nor a primary detractor of academic self-efficacy among senior secondary biology students in the study area.

Conclusion

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The non-significant relationship between the usage of AI-assisted tools and biology self-efficacy implies that integrating AI into secondary science classrooms does not inherently alter or destabilize the pre-existing confidence baselines of learners. Furthermore, given the lack of statistically meaningful differences in self-efficacy profiles across gender groups, it is concluded that current educational AI integration strategies within the study area should prioritize universal technological empowerment and accessible infrastructure rather than gender-segregated interventions.

Recommendations

1. Because the findings revealed that AI usage does not have a statistically significant relationship with student self-efficacy, future empirical research should be conducted in the region to determine if AI-assisted instruction significantly impacts alternative student learning outcomes, such as performance, conceptual retention, interest, and intrinsic motivation.
2. Educational institutions should design and deploy comprehensive AI literacy modules focusing on the practical application, operations, and ethical boundaries of AI to ensure students interact with assistive technologies productively and confidently.

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Effect of Curriculum Evaluation on Academic Achievement among Secondary School Students in Katsina State, Nigeria

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Abstract

Curriculum evaluation is an essential component of educational quality assurance and serves as a mechanism for determining the effectiveness, relevance, and efficiency of educational programmes. Despite various curriculum reforms implemented in Nigeria, concerns continue to be raised regarding the academic achievement of secondary school students, particularly in Katsina State. This study investigated the effect of curriculum evaluation on academic achievement among secondary school students in Katsina State, Nigeria. The study adopted a quasi-experimental research design involving pre-test and post-test non-equivalent control groups. The population consisted of 15,333 Junior Secondary School (JSS II) students in public secondary schools in Katsina State. A sample of 384 students was selected using multistage sampling procedures. The Curriculum Evaluation Intervention Package (CEIP) and Junior Secondary Academic Achievement Test (JSAAT) were used for data collection. The instruments were validated by experts in Educational Measurement and Evaluation and Curriculum Studies. Reliability coefficients of 0.86 and 0.88 were obtained using Cronbach Alpha and Kuder-Richardson Formula 20 respectively. Data were analysed using mean, standard deviation, and Analysis of Covariance (ANCOVA) at 0.05 level of significance. Findings revealed that curriculum evaluation significantly improved students' academic achievement. Students exposed to curriculum evaluation-based instructional strategies performed significantly better than those taught using conventional approaches. The study concluded that systematic curriculum evaluation enhances instructional effectiveness, improves curriculum implementation, and contributes positively to students' academic achievement. It was recommended that educational stakeholders institutionalize periodic curriculum evaluation and provide teachers with adequate training in curriculum implementation and assessment practices.

Keywords: Curriculum Evaluation, Academic Achievement, Educational Evaluation &Students.

Background to the Study

Education occupies a central position in national development because it serves as a means through which knowledge, skills, attitudes, and values are transmitted to learners. The effectiveness of any educational system largely depends on the quality of its curriculum and the extent to which the curriculum achieves its intended objectives. Curriculum evaluation therefore remains one of the most important processes in educational planning, implementation, and improvement. Curriculum evaluation refers to the systematic collection, analysis, and interpretation of information regarding curriculum effectiveness for the purpose of determining whether educational objectives are being achieved and identifying areas requiring improvement. According to Tyler's Objective-Centred

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Evaluation Model, curriculum evaluation determines the degree to which intended educational objectives are attained through instructional activities. Contemporary scholars maintain that curriculum evaluation provides evidence-based information for curriculum review, revision, implementation, and quality assurance (Akinbote & Olatoye, 2024). The importance of curriculum evaluation has increased significantly in recent years due to rapid technological advancement, globalization, changing labour market demands, and evolving educational priorities. Educational systems across the world continuously evaluate their curricula to ensure relevance, effectiveness, and responsiveness to societal needs. In Nigeria, curriculum reforms have been introduced to improve educational quality, promote learner-centred instruction, and enhance academic achievement among students.

Academic achievement refers to the extent to which students attain desired educational goals as measured through examinations, tests, assignments, and other assessment procedures. Academic achievement serves as an important indicator of educational effectiveness and quality. Researchers have consistently identified curriculum-related factors as significant determinants of students' academic achievement (Adeyemi & Yusuf, 2023). In Katsina State, concerns have been raised regarding students' performance in both internal and external examinations. Reports from educational stakeholders indicate that many students experience difficulties in achieving expected learning outcomes. These concerns have generated interest in examining factors that may contribute to improved academic achievement. One such factor is curriculum evaluation. Effective curriculum evaluation enables educational authorities to identify strengths and weaknesses in curriculum implementation, instructional strategies, learning materials, assessment practices, and teacher effectiveness. Findings from curriculum evaluation provide useful information for educational improvement and informed decision-making. Theoretical perspectives emphasize the importance of curriculum evaluation in educational improvement. Tyler's Objective-Centred Evaluation Theory argues that educational programmes should be evaluated based on clearly stated objectives and measurable outcomes. Similarly, Stufflebeam's CIPP (Context, Input, Process, Product) Evaluation Model views evaluation as a continuous process for improving educational programmes and informing decision-making. Recent empirical studies have reported positive relationships between curriculum evaluation and educational outcomes. Olatunde and Bello (2024) found that curriculum evaluation practices significantly improved instructional quality and students' learning outcomes. Similarly, Mohammed and Hassan (2025) reported that schools implementing systematic curriculum evaluation recorded higher levels of academic achievement than schools with weak evaluation systems. Despite these findings, limited empirical studies have specifically investigated the effect of curriculum evaluation on academic achievement among secondary school students in Katsina State. This study therefore seeks to fill this gap.

Statement of the Problem

The Nigerian educational system has witnessed several curriculum reforms aimed at improving educational quality and enhancing students' academic achievement. Despite these reforms, concerns continue to exist regarding the effectiveness of curriculum implementation and students' academic performance at secondary school level. In Katsina State, reports from educators, parents, and examination bodies indicate persistent challenges in students' academic achievement. Many students fail to attain expected learning outcomes despite the availability of curriculum guidelines and instructional resources. This situation raises questions regarding the extent to which curriculum implementation aligns with intended curriculum objectives. Although curriculum evaluation is expected to facilitate continuous improvement in educational programmes, evidence suggests that

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curriculum evaluation practices are not consistently implemented in many schools. Consequently, weaknesses in curriculum implementation may remain unidentified, thereby affecting students' academic achievement. Previous studies have examined various factors influencing academic achievement; however, limited attention has been given to the effect of curriculum evaluation on students' academic achievement in Katsina State. Therefore, this study investigates whether curriculum evaluation can significantly improve academic achievement among junior secondary school students in Katsina State, Nigeria.

Objective of the Study

The study sought to:

1. Determine the effect of curriculum evaluation on academic achievement among secondary school students in Katsina State.

Research Question

1. What is the effect of curriculum evaluation on academic achievement among secondary school students in Katsina State?

Research Hypothesis

H_{01}: Curriculum evaluation has no significant effect on academic achievement among secondary school students in Katsina State.

Research Methodology

The study adopted a quasi-experimental research design involving pre-test and post-test non-equivalent control groups. The population and sample of 15,333 and 384 Junior Secondary School II students respectively enrolled and selected from public Junior secondary schools in Katsina State. A multistage sampling procedure involving stratified sampling, purposive sampling, and simple random sampling techniques was employed. Two instruments were used: Curriculum Evaluation Intervention Package (CEIP) and Secondary Academic Achievement Test (SAAT). The instruments were validated by three experts in Educational Measurement and Evaluation and Curriculum Studies.

Reliability

Instrument	Reliability Coefficient
CEIP	0.86
JSAAT	0.88

Experimental Procedure

The experimental group was exposed to curriculum evaluation-based instructional strategies for eight weeks, while the control group received conventional instruction.

Pre-test scores were collected before treatment, while post-test scores were collected after treatment.

Method of Data Analysis

Research question was answered using mean and standard deviation.

Hypothesis was tested using Analysis of Covariance (ANCOVA) at 0.05 level of significance.

Presentation of Results

Research Question One

What is the effect of curriculum evaluation on academic achievement among junior secondary school students in Katsina State?

To answer this research question, the mean and standard deviation of the pre-test and post-test scores of students in the experimental and control groups were computed.

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Table 1

Mean and Standard Deviation of Pre-test and Post-test Scores of Students Exposed to Curriculum Evaluation and Conventional Instruction

Group	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	Mean Gain
Experimental Group (Curriculum Evaluation)	192	42.36	8.21	71.84	7.34	29.48
Control Group (Conventional Instruction)	192	41.91	8.47	58.27	8.12	16.36

Table 1 indicates that students in the experimental group recorded a pre-test mean score of 42.36 and a post-test mean score of 71.84, resulting in a mean gain of 29.48. Students in the control group recorded a pre-test mean score of 41.91 and a post-test mean score of 58.27, resulting in a mean gain of 16.36. The results suggest that students exposed to curriculum evaluation-based instructional strategies performed better than students taught using conventional instructional approaches.

Hypothesis Testing

Hypothesis One

H_{01}: Curriculum evaluation has no significant effect on academic achievement among junior secondary school students in Katsina State.

Table 2

Analysis of Covariance (ANCOVA) Showing the Effect of Curriculum Evaluation on Academic Achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	18972.461	2	9486.231	112.814	.000
Intercept	51243.716	1	51243.716	609.215	.000
Pre-test	4326.584	1	4326.584	51.439	.000
Treatment Group	14389.772	1	14389.772	171.087	.000*
Error	32048.315	381	84.116		
Total	1687931.000	384			
Corrected Total	51020.776	383			

R^2 = .372 (Adjusted R^2 = .369)

Significant at p < .05

Decision

Since the probability value (p = .000) is less than the alpha level of .05, the null hypothesis is rejected. The ANCOVA result shows that curriculum evaluation had a statistically significant effect on academic achievement among junior secondary school students in Katsina State, F(1,381) = 171.087, p < .05. The effect size (R^2 = .372) indicates that curriculum evaluation accounted for approximately 37.2% of the variance in students' academic achievement. This implies that curriculum evaluation contributed significantly to improving students' academic performance.

Discussion of Findings

The findings of this study revealed that curriculum evaluation significantly improved academic achievement among secondary school students in Katsina State. Students exposed to curriculum evaluation-based instructional practices achieved higher post-test scores than those taught through conventional instructional methods. The significant difference observed between the experimental and control groups demonstrates the effectiveness of curriculum evaluation in enhancing learning

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outcomes. The finding may be attributed to the systematic monitoring and assessment of curriculum implementation, which enabled teachers to align instructional practices with curriculum objectives. Curriculum evaluation helped identify instructional weaknesses, improve teaching methods, and ensure that learning experiences matched intended educational goals. The result supports the position of Tyler's Objective-Centred Evaluation Theory, which emphasizes that educational programmes should be evaluated according to the extent to which stated objectives are achieved. Through continuous evaluation, teachers and curriculum planners can determine whether learning objectives are being attained and make necessary adjustments to improve instructional effectiveness. The finding is consistent with Adeyemi and Yusuf (2023), who reported that effective curriculum evaluation significantly improved students' academic performance in secondary schools. The finding also agrees with Olatunde and Bello (2024), who found that curriculum evaluation enhanced instructional quality and students' learning outcomes. Similarly, Mohammed and Hassan (2025) observed that schools implementing regular curriculum evaluation practices recorded significantly better academic performance than schools lacking structured evaluation systems. Ibrahim and Garba (2025) further reported that curriculum evaluation contributed significantly to educational quality assurance and students' academic success. The finding therefore confirms that curriculum evaluation remains an indispensable component of educational quality improvement and academic achievement enhancement.

Educational Implications of the Study

The findings of this study have important implications for educational policy, curriculum development, educational measurement, and school administration.

1. Curriculum Evaluation Promotes Quality Assurance; Regular curriculum evaluation provides evidence regarding curriculum effectiveness and facilitates educational quality assurance.
2. Curriculum Evaluation Enhances Students' Achievement; The significant improvement observed among students exposed to curriculum evaluation indicates that evaluation contributes positively to learning outcomes.
3. Evidence-Based Educational Decision-Making; Curriculum evaluation provides empirical information that assists policymakers in making informed educational decisions.
4. Improved Curriculum Implementation; Curriculum evaluation helps identify implementation gaps and promotes effective delivery of curriculum content.
5. Improved Teacher Effectiveness; Teachers become more reflective and responsive when curriculum evaluation findings are utilized for instructional improvement.
6. Better Resource Utilization; Curriculum evaluation helps identify resource needs and ensures efficient allocation of educational resources.
7. Strengthening Educational Accountability; Evaluation findings enhance accountability among teachers, administrators, and curriculum planners.

Conclusion

Based on the findings of this study, it was concluded that curriculum evaluation significantly enhances academic achievement among secondary school students in Katsina State. Students who were exposed to curriculum evaluation-based instructional strategies demonstrated significantly higher academic achievement than their counterparts who received conventional instruction. The study established that curriculum evaluation serves as an effective mechanism for improving curriculum implementation, instructional delivery, and learning outcomes. Consequently, curriculum evaluation should be regarded as an essential component of educational quality assurance and educational improvement initiatives in Katsina State and Nigeria at large.

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Recommendations

Based on the findings and conclusion of the study, the following recommendations were made:

1. Educational authorities should institutionalize regular curriculum evaluation at all levels of education.
2. Teachers should receive continuous professional development training on curriculum implementation and evaluation techniques.
3. School administrators should establish curriculum monitoring and evaluation committees within schools.
4. Curriculum evaluation findings should be used to inform curriculum review and revision processes.
5. Government should provide adequate resources to support curriculum evaluation activities.
6. Educational planners should integrate evaluation outcomes into policy formulation and implementation.
7. The Katsina State Ministry of Basic and Secondary Education should strengthen quality assurance mechanisms across schools.
8. Curriculum specialists should collaborate with teachers to ensure effective implementation of curriculum innovations.
9. Parents and community stakeholders should be involved in curriculum evaluation processes where appropriate.
10. Further studies should investigate additional curriculum variables that influence students' academic achievement.

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Correlation Between Video-Based Learning Resources and Digital Library Platforms on Academic Performance among Business Education Students in Federal University Dutsin-Ma, Katsina State

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Abstract

This study examined video-based learning resources and digital library and e-resource platforms as correlates of the academic performance of Business Education students in Federal University Dutsin-Ma, Katsina State. Two objectives guided the study: to examine the extent to which video-based learning resources relate to academic performance, and to assess the extent to which digital library and e-resource platforms relate to academic performance. A descriptive correlational survey design was adopted. The population comprised all 234 registered Business Education students in the Department of Educational Management, distributed across four undergraduate levels. A sample of 148 respondents was drawn using the Krejcie and Morgan (1970) table, applying a proportionate stratified random sampling technique across the four levels. Data were collected with a self-developed instrument, the Online Learning Platforms and Academic Performance Questionnaire (OLPAPQ), validated by three specialists at Federal University Dutsin-Ma and yielding a Cronbach alpha reliability coefficient of .83 on pilot testing. Research questions were answered using mean and standard deviation, with 2.50 as the criterion for acceptance, while the two null hypotheses were tested using simple linear regression at the .05 level of significance. Findings showed that respondents agreed that video-based learning resources (grand mean = 3.23) and digital library and e-resource platforms (grand mean = 3.24) are positively associated with their academic performance. Both hypotheses were rejected: video-based learning resources significantly predicted academic performance ($R = .682$, $R^2 = .465$, $F = 127.84$, $p < .05$), as did digital library and e-resource platform use ($R = .703$, $R^2 = .494$, $F = 143.17$, $p < .05$), with the latter showing the stronger relationship. The study concluded that deliberate, structured engagement with both video content and digital library resources meaningfully supports academic success among Business Education students. It was recommended that the Department of Educational Management institutionalise digital library orientation for new students and that lecturers curate topic-specific video resources rather than leaving students to search unguided.

Keywords: Online Learning Platforms, Video-Based Learning, Digital Library, E-Resources, Academic Performance, Business Education

Introduction

University education in Nigeria has, over the past decade, been reshaped by the steady spread of affordable smartphones and mobile internet access, developments that have quietly altered how students supplement what happens inside the lecture hall. In the digital age, the effective management of educational programmes is pivotal for the advancement of nations, particularly in regions like Nigeria where the demand for quality education is high (Busa, et al, 2024). Federal University Dutsin-Ma, situated in a part of Katsina State where electricity supply and campus

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infrastructure have historically lagged behind older southern universities, offers a particularly instructive setting in which to examine what this shift has actually meant for learning outcomes. Business Education, as a field of study, trains students for roles in commerce, accounting, entrepreneurship and office administration, and it is a discipline in which currency of knowledge matters: accounting software changes, marketing examples date quickly, and textbook material alone rarely keeps pace with practice (Ojo & Awe, 2020). Online platforms, in principle, are well placed to close that gap, offering demonstration videos, current case material and searchable scholarly literature that a fixed weekly lecture cannot always provide.

Two categories of online engagement are of particular interest to Business Education specifically. The first is video-based learning, ranging from recorded lecture capture to open platforms such as YouTube, through which students can watch worked demonstrations and revisit difficult explanations at their own pace. Babalola and Aina (2024), studying undergraduates at the University of Ilorin, found that platforms of this kind were associated with measurable gains in students' self-reported academic performance, particularly where video content was used to clarify, rather than simply replace, classroom instruction. The second is digital library and e-resource use, through tools such as Google Scholar, ResearchGate and institutional database subscriptions, which allow students to move beyond prescribed textbooks into current, peer-reviewed material. Ogunbodede and Oribhabor (2022) reported a significant positive relationship between digital resource usage and undergraduate academic performance in their Nigerian case study, while Adenariwo and Sulyman (2022) found that the availability and accessibility of electronic information resources in academic libraries were themselves significant predictors of student academic performance. The COVID-19 pandemic accelerated the adoption of both categories of platform across Nigerian tertiary institutions, exposing considerable unevenness in digital readiness between better-resourced and less-resourced universities (Azubuike, Adegboye & Quadri, 2021; Adeoye, Adanikin & Adanikin, 2020). Federal University Dutsin-Ma was among the institutions that had to improvise digital alternatives during the lockdown period, and the habits formed during that period appear to have persisted since campuses reopened. Yet enthusiasm for digital learning tools is not, on its own, evidence that they work as intended in every context. Asogwa, Nkanu and Sabo (2022), examining e-learning readiness in federal colleges of education in North-East Nigeria, found that infrastructural constraints, including data cost and irregular power, continued to shape whether digital engagement translated into genuine academic gain. Whether video-based and digital library engagement specifically, rather than online platform use in general, are associated with the academic performance of Business Education students at Federal University Dutsin-Ma has not previously been established with local, discipline-specific data, and it is this gap that the present study addresses.

Statement of the Problem

Business Education students at Federal University Dutsin-Ma are increasingly turning to online video content and digital library platforms as part of their study routines, yet the department has no systematic evidence of whether this engagement is actually associated with stronger academic performance or is simply a habit that feels productive without delivering measurable benefit. This distinction matters because video watching and database searching are not inherently equal in value: a student passively streaming unrelated content is doing something quite different from one actively using a curated video to resolve a specific misunderstanding, or one systematically searching a scholarly database to strengthen an assignment. Without evidence distinguishing the two categories examined in this study, lecturers cannot confidently recommend one form of engagement over

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another, and the department cannot justify investment in digital library subscriptions or video-based instructional design with any specificity. Constrained further by unreliable electricity and the cost of mobile data typical of this part of Katsina State, students' choices about which platforms are worth the investment of scarce data and time carry real consequences. This study was designed to supply the missing, locally grounded evidence.

Purpose of the Study

The purpose of this study was to examine video-based learning resources and digital library and e-resource platforms as correlates of academic performance among Business Education students in Federal University Dutsin-Ma, Katsina State. Specifically, the study sought to:

1. examine the extent to which video-based learning resources relate to the academic performance of Business Education students in Federal University Dutsin-Ma, Katsina State; and
2. assess the extent to which digital library and e-resource platforms relate to the academic performance of Business Education students in Federal University Dutsin-Ma, Katsina State.

Research Questions

The following research questions guided the study:

1. To what extent do video-based learning resources relate to the academic performance of Business Education students in Federal University Dutsin-Ma, Katsina State?
2. To what extent do digital library and e-resource platforms relate to the academic performance of Business Education students in Federal University Dutsin-Ma, Katsina State?

Hypotheses

The following null hypotheses were tested at the .05 level of significance:

1. Video-based learning resources have no significant influence on the academic performance of Business Education students in Federal University Dutsin-Ma, Katsina State.
2. Digital library and e-resource platforms have no significant influence on the academic performance of Business Education students in Federal University Dutsin-Ma, Katsina State.

Research Methodology

This study adopted a descriptive correlational survey design, appropriate for examining the relationship between naturally occurring patterns of online platform use and academic performance without manipulating any variable. The population comprised all 234 registered Business Education students in the Department of Educational Management, Federal University Dutsin-Ma, distributed across four undergraduate levels. The sample size of 148 was determined using the Krejcie and Morgan (1970) table for determining sample size from a given population. A proportionate stratified random sampling technique was applied, with the population divided into four strata corresponding to academic level, and respondents drawn from each stratum in proportion to its share of the total population. Data were collected using a structured instrument, the Online Learning Platforms and Academic Performance Questionnaire (OLPAPQ), developed by the researcher. The instrument contained a demographic section and a response section measured on a four-point Likert scale of Strongly Agree (4), Agree (3), Disagree (2) and Strongly Disagree (1), with five items addressing video-based learning resources and five items addressing digital library and e-resource platforms, alongside items capturing self-reported academic performance. Content validity was established through review by three specialists at Federal University Dutsin-Ma, two in educational administration and planning and one in measurement and evaluation. A pilot administration to 20 students outside the main sample yielded a Cronbach alpha reliability coefficient of .83, indicating high internal consistency. All 148 administered copies were retrieved fully completed, a 100 percent return rate. Research questions were answered using mean and standard deviation, with a criterion

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mean of 2.50 as the cut-off for acceptance. The two hypotheses were tested using simple linear regression analysis at the .05 level of significance, with academic performance as the dependent variable in each case.

Presentation of Results

Research Question One: To what extent do video-based learning resources relate to the academic performance of Business Education students in Federal University Dutsin-Ma, Katsina State?

Table 2: Mean and Standard Deviation of Responses on Video-Based Learning Resources and Academic Performance

S/N	Item Statements	N	Mean	SD	Remark
1	I use educational videos on platforms such as YouTube and Coursera to learn Business Education concepts.	148	3.21	.79	Agree
2	Video-based learning resources help me better understand complex Business Education topics.	148	3.37	.85	Agree
3	Watching recorded lectures online has improved my performance in Business Education examinations.	148	3.02	.73	Agree
4	Video tutorials have helped me clarify concepts I did not fully understand during classroom instruction.	148	3.44	.87	Agree
5	My use of video-based learning resources has positively influenced my academic performance in Business Education.	148	3.11	.75	Agree
	Grand Mean		**3.23**	**.80**	**Agree**

Table 2 shows that all five items exceeded the 2.50 benchmark, with mean scores ranging from 3.02 to 3.44 and a grand mean of 3.23. Item 4, on video tutorials helping students clarify concepts not fully understood in class, recorded the highest mean (3.44), indicating that the most valued function of video content, in students' own experience, is targeted clarification rather than wholesale replacement of the lecture. Item 3, which links video use directly to examination performance, recorded the comparatively lowest mean (3.02), suggesting students perceive the path from watching a video to a better examination score as less direct than the path to improved conceptual understanding. This pattern is broadly consistent with Babalola and Aina (2024), who found that Ilorin undergraduates valued video content primarily for comprehension rather than as a direct substitute for examination preparation.

Research Question Two: To what extent do digital library and e-resource platforms relate to the academic performance of Business Education students in Federal University Dutsin-Ma, Katsina State?

Table 3: Mean and Standard Deviation of Responses on Digital Library and E-Resource Platforms and Academic Performance

S/N	Item Statements	N	Mean	SD	Remark
6	I use online platforms such as Google Scholar, ResearchGate, or digital libraries to access academic materials for my studies.	148	3.18	.78	Agree
7	Access to digital library resources has improved the quality of my academic assignments and coursework.	148	3.31	.83	Agree
8	Online academic databases have helped me access current and relevant Business Education research and materials.	148	3.09	.75	Agree

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S/N	Item Statements	N	Mean	SD	Remark
9	Using digital e-resource platforms has enhanced my research skills and academic writing in Business Education.	148	3.23	.80	Agree
10	My use of digital library and e-resource platforms has contributed positively to my overall academic performance.	148	3.41	.88	Agree
	Grand Mean		**3.24**	**.81**	**Agree**

Table 3 shows that all five items exceeded the 2.50 benchmark, with a grand mean of 3.24, marginally the higher of the two constructs examined. Item 10, on the overall contribution of digital library and e-resource platforms to academic performance, recorded the highest mean (3.41), while Item 8, on access to current and relevant research, recorded the comparatively lowest mean (3.09), suggesting that students draw more confidently on digital libraries as a general study aid than as a tool for engaging the most recent scholarship in Business Education. This is consistent with Adenariwo and Sulyman (2022), who found that availability and accessibility of electronic information resources significantly predicted student academic performance in Nigerian academic libraries, and with Okigbo and Ikechukwu (2025), who reported that structured use of online platforms was linked to stronger academic achievement among undergraduates in comparable Nigerian university settings.

Hypotheses

Hypothesis One:

Video-based learning resources have no significant influence on academic performance.

Table 4: Simple Linear Regression Result for Video-Based Learning Resources and Academic Performance

Model	R	R^2	Adj. R^2	F	Sig.	Decision
Video-based learning resources → Academic performance	.682	.465	.461	127.84	.000	Rejected

Table 4 shows that video-based learning resources significantly predict academic performance, R = .682, R^2 = .465, F (1, 146) = 127.84, p = .000. Approximately 46.5% of the variance in academic performance is explained by the extent of video-based learning resource use. Since p < .05, Ho1 was rejected, confirming a significant positive relationship between video-based learning resources and academic performance.

Hypothesis Two:

Digital library and e-resource platforms have no significant influence on academic performance.

Table 5: Simple Linear Regression Result for Digital Library and E-Resource Platforms and Academic Performance

Model	R	R^2	Adj. R^2	F	Sig.	Decision
Digital library and e-resource platforms → Academic performance	.703	.494	.491	143.17	.000	Rejected

Table 5 shows that digital library and e-resource platform use significantly predicts academic performance, R = .703, R^2 = .494, F (1, 146) = 143.17, p = .000. Approximately 49.4% of the variance in academic performance is explained by digital library and e-resource platform use, the stronger of the two relationships examined. Since p < .05, Ho2 was rejected, confirming a significant positive relationship between digital library and e-resource platforms and academic performance. Taken together, these results indicate that both forms of online engagement are meaningfully associated with academic performance, with digital library and e-resource use showing a marginally stronger relationship than video-based learning. This finding aligns with Ogunbodede and Oribhabor (2022),

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who similarly found digital resource usage to be a strong correlate of undergraduate academic performance in Nigeria, and extends the work of Eze, Chinedu-Eze and Bello (2018) on e-learning utilisation by demonstrating that, within a single Business Education programme, the specific act of engaging scholarly databases carries slightly more weight than watching instructional video content. The comparatively higher explanatory power of digital library use may reflect the discipline itself: Business Education depends on current commercial and policy information that scholarly databases are better positioned to supply than general video platforms, a point consistent with Ojo and Awe (2020), who argued that ICT-based instruction in Nigerian business education must be current and practically grounded to be effective.

Conclusion

This study concludes that video-based learning resources and digital library and e-resource platforms are both significant, positive correlates of academic performance among Business Education students in Federal University Dutsin-Ma, with digital library engagement showing the somewhat stronger relationship of the two. Students who make deliberate use of these platforms, rather than engaging with them passively or incidentally, appear to gain measurable academic benefit. In a resource constrained setting such as Dutsin-Ma, where data cost and electricity supply limit how much time students can spend online, understanding which forms of digital engagement carry the most weight offers practical guidance for how limited study time and data allowances might be prioritised.

Recommendations

Based on the findings, the following recommendations are made:

1. The Department of Educational Management should institutionalise structured digital library orientation for Business Education students at 100 Level, ensuring early competence in navigating Google Scholar, ResearchGate and any university-subscribed databases, given the strength of the relationship between digital library use and academic performance found in this study.
2. Lecturers should curate specific, topic-relevant video resources for historically difficult areas of the Business Education curriculum, rather than leaving students to search unguided, and should design short follow-up tasks that require active engagement with recommended videos.
3. University management should continue to invest in stable, affordable campus internet access, since the benefits identified in this study depend on students being able to reach video and digital library platforms reliably and consistently.

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Effect of Model-Aided Inquiry-Based Learning on Academic Performance in Basic Science among Students with Varied Reasoning abilities in Benue State, Nigeria

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Abstract

Persistent poor academic performance in Basic Science among Junior Secondary School students in Benue State, Nigeria, has been linked to the abstract nature of scientific concepts and continued reliance on teacher-centred instruction that limits active investigation. To address this problem, this study examined the effect of Model-Aided Inquiry-Based Learning (MAIBL) on the academic performance of students with varied reasoning abilities in Basic Science. The population comprised 18,420 JSS II students in 62 public co-educational schools in Zone B, Benue State, during the 2024/2025 session. A sample of 88 students was drawn from two intact classes in two co-educational schools in Makurdi Local Government Area using purposive sampling. A quasi-experimental, pre-test post-test non-equivalent control group design was adopted, with one school (n = 42) assigned to MAIBL and the other (n = 46) to the Conventional Discussion Method. Two research questions were answered, and two null hypotheses tested at 0.05 significance. Data were collected using the Basic Science Performance Test (BSPT) and Reasoning Ability Test (RAT), which classified students into high, moderate, and low reasoning categories. Both instruments were validated by three experts and yielded reliability coefficients of 0.82 and 0.79 respectively, using KR-20. Data were analysed using Mean, Standard Deviation, and ANCOVA. Results showed a significant difference in performance between students taught using MAIBL and CDM, $F(1, 85) = 80.075$, $p < .001$, partial $\eta^2 = .485$, favouring MAIBL. A significant difference was also found across reasoning ability levels under MAIBL, $F(2, 39) = 10.033$, $p < .001$, partial $\eta^2 = .340$, with high-reasoning students gaining most. It was recommended that Basic Science teachers integrate models into inquiry-based lessons to enhance performance across all reasoning levels.

Key Words: Model-aided inquiry-based learning, Performance, reasoning ability, Basic Science.

Introduction

Basic Science occupies a central position in the Nigerian Junior Secondary School curriculum, providing an integrated foundation in science and preparing learners for specialised study in Biology, Chemistry, and Physics at the senior secondary level. Beyond content knowledge, the subject cultivates inquiry skills, scientific thinking, problem-solving ability, and the application of scientific knowledge to everyday life (Mardonov, 2019; Ode & Fakaa, 2023). Despite this importance, students in Benue State continue to record inconsistent academic performance in Basic Science examinations (Benue State Teaching Service Board, 2023), a pattern consistent with broader challenges in Nigerian science education, even at the senior secondary level, where learning difficulties are attributed to the abstract nature of scientific concepts and the persistence of teacher-centred instruction (WAEC, 2022). This worries stakeholders in science education and requires research to find instructional strategies that actively engage learners while providing adequate cognitive support. The growing emphasis on learner-centred pedagogy has positioned Inquiry-Based Learning (IBL) as a key strategy in science teaching and learning. According to Abdi (2014), IBL engages learners in questioning, investigating, gathering and interpreting evidence, and constructing explanations, positioning them

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as active participants in knowledge construction rather than passive recipients of information. Empirical evidence supports the value of inquiry-oriented instruction, particularly when appropriately guided (Abdi, 2014; Furtak et al., 2012). In Nigeria, Enemarie et al. (2025) found that students taught Basic Science through guided inquiry outperformed those taught through demonstration. In other contexts, structured learner-centred approaches have similarly improved performance (Omaga & Kpiranyam, 2024). However, inquiry can impose considerable cognitive demands when complex concepts are explored without adequate support (Etobro & Fabinu, 2017), highlighting the need for adoption of a strategy that preserve inquiry's active features while offering concrete or visual scaffolding, with the use of models.

Model-Aided Inquiry-Based Learning (MAIBL) is a strategy that integrates models, physical, pictorial, symbolic, mathematical, or conceptual representations, into inquiry activities, helping learners visualise and explain phenomena that are otherwise difficult to observe directly (Griskevica & Iltners, 2021). Within MAIBL, learners interact with models, investigate questions, interpret evidence, and apply emerging understanding to new situations, consistent with constructivist principles of active, meaningful knowledge construction and promoting both hands-on and mind-on engagement (Achor et al., 2015; Etobro & Fabinu, 2017). Related studies reinforce the value of representational, cognitively engaging instruction. Kpiranyam et al. (2023) found that Biology students taught using a Graphic Advance Organizer achieved higher performance and retention than those taught through discussion, while Kpiranyam et al. (2024) reported that concept mapping enhanced students' critical thinking relative to conventional instruction. Although these findings support the value of representational structures in organising and connecting information, they do not establish whether embedding models directly within an inquiry process yields comparable benefits in Basic Science, or whether such benefits vary with learners' reasoning ability, which Achor and Musa (2021) describe as the capacity to think logically, relate ideas, draw conclusions, and apply information to solve problems. Since Basic Science requires learners to interpret observations, identify relationships, and explain phenomena, differences in reasoning ability may shape how effectively learners engage with inquiry and use models to construct explanations.

While related Benue State research links cognitively engaging strategies to improved critical thinking and performance (Samba & Kpiranyam, 2021; Kpiranyam et al., 2021), critical thinking and reasoning ability remain distinct constructs, leaving open whether reasoning ability moderates instructional effectiveness. This potential interaction can be understood through Piagetian theory, which holds that learners progressively develop capacities for abstract, hypothetical, and logical reasoning (Piaget, 1964). At the secondary level, learners vary in their readiness for independent abstract reasoning; models embedded in inquiry may bridge this variation by offering concrete representations through which learners can explore relationships before advancing to abstract explanation. Reasoning ability may therefore influence how learners respond to MAIBL during the learning process and, consequently, their resulting academic performance in Basic Science.

The present study uses the Conventional Discussion Method (CDM) as its comparison condition. The CDM is teacher-directed, involving presentation of subject matter followed by teacher-led questioning, and offers fewer opportunities for sustained investigation or model-supported representation than MAIBL. Demirçalı and Selvi (2022) reported that model-based teaching produced significantly higher performance than conventional instruction, and Alqawasmi et al. (2024) reported comparable gains for inquiry-based instruction. Within Nigeria, Abdullahi et al. (2021) similarly

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found that secondary school Biology students taught using the 7E instructional strategy achieved and retained more than those taught through traditional, teacher-centred methods. Comparing MAIBL with CDM thus helps clarify whether performance differences arise from the combined inquiry-and-model-based support that characterises MAIBL, rather than mere exposure to instruction generally. Although evidence generally favours inquiry-based and model-supported strategies, guided inquiry (Furtak et al., 2012) and model-supported instruction (Gee & Wong, 2012; Ronoh et al., 2020) having both improved outcomes, findings are not uniformly consistent; Jerrim et al. (2019), for instance, found limited association between inquiry frequency and science performance, suggesting that effectiveness depends on how inquiry is structured and on learner characteristics. Despite growing evidence on inquiry-based and model-supported instruction, limited research has examined whether MAIBL differentially affects Basic Science performance according to students' reasoning ability, particularly whether it offers an advantage over CDM among learners of varying reasoning levels in Benue State, Nigeriaa. Addressing this gap matters because instructional effectiveness may depend not only on the strategy employed but on learners' cognitive readiness to engage with its demands. This study therefore examined the effect of Model-Aided Inquiry-Based Learning on the academic performance of students with differing reasoning abilities in Basic Science in Benue State, Nigeria, comparing MAIBL with CDM and testing whether reasoning ability moderated the effect of instructional strategy on academic performance.

Statement of the Problem

Despite the recognised importance of Basic Science as a foundation for future specialisation in Biology, Chemistry, and Physics, students in Zone B, Benue State continue to record persistently inconsistent academic performance in Basic Science examinations. This performance has been linked to the abstract nature of some Basic Science concepts and the continued dominance of teacher-centred, conventional discussion methods that offer learners limited opportunity for active investigation or conceptual visualisation. While Inquiry-Based Learning has been advanced as a remedy, unsupported inquiry can impose excessive cognitive demands on learners, particularly when abstract concepts are explored without concrete or representational support. Model-Aided Inquiry-Based Learning (MAIBL) has therefore been proposed to integrate models into inquiry activities to ease this cognitive burden; however, empirical evidence on its effectiveness relative to conventional instruction in Basic Science remains limited, particularly within learners in Zone B, Benue State. Moreover, existing studies on related strategies, such as graphic organisers and concept mapping, have not established whether students' reasoning ability moderates the effectiveness of model-supported inquiry strategies. Consequently, it remains unclear whether MAIBL confers an academic performance advantage over the Conventional Discussion Method, and whether such an advantage, if it exists, is consistent across learners with differing levels of reasoning ability. This study therefore addressed the effect of Model-Aided Inquiry-Based Learning on the academic performance of students with varied reasoning abilities in Basic Science in Benue State.

Research Questions

The following research questions guided the study:

1. What is the difference in the mean academic performance scores of students taught Basic Science using model-aided inquiry-based learning and those taught using the conventional discussion method?
2. What is the difference in the mean academic performance scores of students with high, medium, and low reasoning abilities when taught Basic Science using model-aided inquiry-based learning?

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Hypotheses

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

1. There is no significant difference in the mean academic performance scores of students taught Basic Science using model-aided inquiry-based learning and those taught using the conventional discussion method.
2. There is no significant difference in the mean academic performance scores of students with varied reasoning abilities (high, medium, and low) when taught Basic Science using model-aided inquiry-based learning.

Research Methodology

A quasi-experimental pre-test, post-test non-equivalent control group design was adopted for this study. This design is appropriate because the researcher could not randomly assign individual students to groups; instead, intact classes were used as the unit of assignment. The population consisted of 18,420 JSS II students in 62 public co-educational upper basic secondary schools in Zone B, Benue State, for the 2024/2025 academic session (Benue State Teaching Service Board, 2023). Zone B was purposively selected because of its characteristically mixed urban-rural learner composition and persistent below-average performance in science subjects. The sample consisted of 88 JSS II students drawn from two co-educational public secondary schools in Makurdi Local Government Area using purposive sampling. These schools were selected on the basis of similarity in enrolment size, comparable pre-test mean scores (verified statistically), and availability of qualified Basic Science teachers willing to serve as research assistants. One school (n = 42) was randomly assigned to the experimental group (model-aided inquiry-based learning) and the other (n = 46) to the control group (conventional discussion method). Two instruments were used for data collection: the Basic Science Performance Test (BSPT) and the Reasoning Ability Test (RAT). The BSPT comprised 50 multiple-choice items drawn from the JSS II Basic Science curriculum, covering topics in physical science, life science, and earth science. The RAT comprised 20 multiple-choice items and assessed six reasoning modes: conservation, proportional, controlling variables, probabilistic, correlational, and combination reasoning. Based on RAT scores, students were classified into high (RAT ≥ 70%), medium (40% – 69%), and low (< 40%) reasoning categories. Both instruments were validated by three experts: two from the Department of Science and Mathematics Education and one from the Department of Educational Measurement and Evaluation, Rev Fr Moses Orshio Adasu University, Makurdi. Reliability was determined through a trial test on 30 JSS II students using the Kuder-Richardson (KR-20) formula, reliability coefficients of 0.82 and 0.79 were obtained for the BSPT and RAT respectively. Two qualified experienced Basic Science teachers from the sampled schools as research assistants. Data were analyzed using Mean and Standard Deviation for research questions and ANCOVA for testing hypotheses, with pre-test scores serving as the covariate to control for initial group differences.

Presentation Of Results

The results of the data analysis and interpretation are presented according to research questions and test of null hypotheses.

Research Question 1: What is the difference in the mean academic performance scores of students taught Basic Science using model-aided inquiry-based learning and those taught using the conventional discussion method? This research question is answered in Table 2.

Table 1: Mean and Standard Deviation of Students' Academic Performance under Model-Aided Inquiry-Based Learning and Conventional Discussion Method

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Gender	Sample (n)	Pre-Test		Pre-Test		$\bar{x}$ Gain
		$\bar{x}$	SD	$\bar{x}$	SD	
Model-Aided Inquiry-Based Learning	42	18.12	5.67	36.14	3.14	18.02
Conventional Discussion Method	46	21.83	5.76	26.78	5.43	4.95
$\bar{x}$ Gain Difference		3.71		9.36		13.07

Table 1 shows that students taught Basic Science using Model-Aided Inquiry-Based Learning had a pre-test mean academic performance score of 18.12 (SD = 5.67), which increased to 36.14 (SD = 3.14) at post-test, giving a mean gain of 18.02. Students taught using the Conventional Discussion Method had a pre-test mean of 21.83 (SD = 5.76), which increased to 26.78 (SD = 5.43) at post-test, with a mean gain of 4.95. At post-test, the mean academic performance score of students taught using Model-Aided Inquiry-Based Learning was 9.36 points higher than that of students taught using the Conventional Discussion Method. The mean gain difference between the two groups was 13.07 in favour of Model-Aided Inquiry-Based Learning. The post-test standard deviations were 3.14 and 5.43 for the Model-Aided Inquiry-Based Learning and Conventional Discussion Method groups, respectively, with a difference of 2.29, indicating that students taught using Model-Aided Inquiry-Based Learning had less variation in their post-test performance. By implication, students' academic performance in but group improved, but the improvement was considerably greater among students taught using Model-Aided Inquiry-Based Learning.

Research Question 2: What is the difference in the mean academic performance scores of students with high, medium, and low reasoning abilities when taught Basic Science using model-aided inquiry-based learning? This research question is answered in Table 2.

Table 2: Mean and Standard Deviation of Students' Academic Performance by Reasoning Ability under Model-Aided Inquiry-Based Learning

Reasoning Ability Levels	Sample (n)	Pre-Test		Post- Test		Mean Gain Within Groups
		$\bar{x}$	SD	$\bar{x}$	SD	
High	12	12.42	3.34	38.83	2.21	26.41
Moderate	17	18.00	4.30	35.71	2.42	17.71
Mean Diff. Between Groups		5.58		3.12		8.70
High	12	12.42	3.34	38.83	2.21	26.41
Low	13	23.54	3.28	34.23	3.17	10.69
Mean Diff. Between Groups		11.12		4.60		15.72
Moderate	17	18.00	4.30	35.71	2.42	17.71
Low	13	23.54	3.28	34.23	3.17	10.69
Mean Diff. Between Groups		5.54		1.48		7.02

Table 2 shows that Model-Aided Inquiry-Based Learning improved students' academic performance across all reasoning ability levels. High-reasoning students increased from a pre-test mean of 12.42

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(SD = 3.34) to a post-test mean of 38.83 (SD = 2.21), yielding the highest mean gain of 26.41. Moderate-reasoning students increased from 18.00 (SD = 4.30) to 35.71 (SD = 2.42), with a mean gain of 17.71, while low-reasoning students increased from 23.54 (SD = 3.28) to 34.23 (SD = 3.17), with a mean gain of 10.69. The gain differences of 8.70, 15.72 and 7.02 between high–moderate, high–low and moderate–low groups, respectively, favoured the higher-reasoning groups. The reduced post-test standard deviations also indicate more consistent performance after the intervention, particularly among high- and moderate-reasoning students.

Hypothesis 1: There is no significant difference in the mean academic performance scores of students taught Basic Science using model-aided inquiry-based learning and those taught using the conventional discussion method. This hypothesis is tested in Table 3.

Table 3: ANCOVA Summary of Students' Academic Performance by Instructional Strategy

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1950.485[a]	2	975.242	48.647	.000	.534
Intercept	7294.274	1	7294.274	363.854	.000	.811
Pretest	26.954	1	26.954	1.345	.249	.016
Strategy	1605.285	1	1605.285	80.075	.000	.485
Error	1704.015	85	20.047			
Total	89592.000	88				
Corrected Total	3654.500	87				

Table 3 indicates that F(1, 85) = 80.075; p = 0.000 < 0.05. Since the probability level is less than the specified alpha level of 0.05, the null hypothesis is rejected. It implies that there is a significant difference in the mean academic performance scores of students taught Basic Science using Model-Aided Inquiry-Based Learning and those taught using the Conventional Discussion Method after controlling for students' pre-test academic performance scores (covariate). The partial eta squared value of 0.485 for instructional strategy implies that 48.5% of the difference in students' academic performance scores can be accounted for by the instructional strategy. This indicates a large effect size. The result suggests that the instructional strategy had a significant effect on students' academic performance in Basic Science.

Hypothesis 2: There is no significant difference in the mean academic performance scores of students with varied reasoning abilities (high, medium, and low) when taught Basic Science using model-aided inquiry-based learning. This hypothesis is tested in Table 4.

Table 4: ANCOVA Summary of Students' Academic Performance by Reasoning Ability under Model-Aided Inquiry-Based Learning

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	137.639[a]	2	68.820	10.033	.000	.340
Intercept	54002.706	1	54002.706	7873.181	.000	.995
Reasoning	137.639	2	68.820	10.033	.000	.340
Error	267.504	39	6.859			
Total	55270.000	42				

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Corrected Total	405.143	41

Table 4 indicates that F(2, 39) = 10.033; p = 0.000 < 0.05. Since the probability level is less than the specified alpha level of 0.05, the null hypothesis is rejected. It implies that there is a significant difference among the mean academic performance scores of students with high, medium, and low reasoning abilities when taught Basic Science using Model-Aided Inquiry-Based Learning, after controlling for students' pre-test academic performance scores (covariate). The partial eta squared value of 0.340 for reasoning ability implies that 34.0% of the difference in students' academic performance scores can be accounted for by their reasoning ability. This indicates a large effect size.

Table 5: Bonferroni Post Hoc Test of Academic Performance by Reasoning Ability Level

(I) Reasoning Ability Level	(J) Reasoning Ability Level	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
High	Moderate	3.1275*	.98745	.009	.6572	5.5977
	Low	4.6026*	1.04843	.000	1.9797	7.2254
Moderate	Low	1.4751	.96493	.403	-.9388	3.8890

Table 5 shows that the Bonferroni post hoc test revealed a significant difference between students with high and moderate reasoning abilities (Mean Difference = 3.1275, p = 0.009 < 0.05) and between students with high and low reasoning abilities (Mean Difference = 4.6026, p = 0.000 < 0.05), indicating that students with high reasoning ability had significantly higher adjusted mean academic performance scores than those with moderate and low reasoning abilities. However, the difference between students with moderate and low reasoning abilities was not significant (Mean Difference = 1.4751, p = 0.403 > 0.05). The findings show that students with high reasoning ability performed significantly better in Basic Science when taught using Model-Aided Inquiry-Based Learning than students with moderate and low reasoning abilities, while students with moderate and low reasoning abilities had comparable academic performance.

Discussion of Findings

The finding showed that both Model-Aided Inquiry-Based Learning and the Conventional Discussion Method improved students' academic performance, with greater improvement under MAIBL. The corresponding hypothesis revealed a significant difference, with instructional strategy accounting for 48.5% of the variance, indicating a large effect. This finding may be attributed to the active and investigative nature of Model-Aided Inquiry-Based Learning, which engages students in observing and manipulating models, investigating concepts, asking questions and constructing explanations, rather than relying mainly on teacher-directed transmission of information. The finding aligns with Abdi (2014), who reported higher academic performance under inquiry-based learning than traditional instruction. Similarly, Ronoh et al. (2020) found greater academic gains with model-supported instruction. Finding aligns with that Demirçal and Selvi, M. (2022) who found that found that the experimental group achieved higher scores in the performance test compared with those of the control group. Findings also support that of Kpiranyam et al. (2024) who reported superior academic performance following concept-mapping-enriched instruction. The findings also align with Kpiranyam et al. (2023) who found that Graphic Advance Organizer instruction outperformed

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discussion. Similarly, it agrees with Enemarie et al. (2025) who reported higher Basic Science academic performance under guided inquiry than demonstration instruction. The superior MAIBL performance may be attributed to physical and conceptual models that made abstract concepts concrete and supported active exploration. As noted by Bybee et al. (2006), structured inquiry promotes active participation and deeper understanding, suggesting that combining models with inquiry can enhance academic performance.

The finding revealed that Model-Aided Inquiry-Based Learning improved students' academic performance across all reasoning ability levels, with the greatest improvement among high-reasoning students. The hypothesis test showed a significant difference in performance across the three reasoning ability levels, with reasoning ability explaining 34.0% of the variance, indicating a large effect. Post hoc analyses confirmed that high-reasoning students significantly outperformed their peers, whereas performance between moderate and low-reasoning students showed no meaningful difference. The findings may be attributed to the interactive and structured nature of Model-Aided Inquiry-Based Learning, which enabled students to explore concepts and draw conclusions. The high-reasoning students benefited more by leveraging their reasoning abilities to interpret models and make connections. The finding agrees with that of Furtak et al. (2012), who found a positive effect of inquiry-based science teaching on student learning, with stronger effects associated with teacher-guided inquiry. Similarly, Heindl (2019) and Kaçar et al. (2021) reported positive effects of inquiry-based learning on academic achievement, particularly among secondary-school students. This finding also tallies with that of Gee and Wong (2012) who found that the use of models or applications during inquiry was positively associated with enhancement of performance. The finding may therefore be attributed to the structured opportunities provided by Model-Aided Inquiry-Based Learning for students to explore concepts, interpret models and construct understanding. The large effect of reasoning ability observed in the present study is also consistent with evidence that inquiry-based approaches can promote higher-order thinking and cognitive engagement in science learning (Antonio & Prudente, 2024). However, Jerrim et al. (2019) found little evidence that the frequency of inquiry-based instruction was associated with higher science performance. The findings imply that Basic Science teachers should integrate Model-Aided Inquiry-Based Learning into classroom instruction, using physical and conceptual models to improve students' academic performance across different reasoning ability levels. They also highlight the need for differentiated scaffolding, teacher training and adequate instructional resources to support learners with varying reasoning abilities effectively.

Conclusion

The study concludes that Model-Aided Inquiry-Based Learning is more effective than the conventional lecture method in improving the academic performance of Upper Basic II students in Basic Science in Benue State. The strategy enhanced performance across all reasoning ability levels, with students of high reasoning ability recording the greatest improvement. The strategy therefore offers a promising approach for improving Basic Science learning and addressing persistent challenges of poor academic performance at the upper basic school level.

Recommendation

Based on the findings, the following recommendations are proposed to enhance students' academic performance in Basic Science:

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1. Basic Science teachers should integrate Model-Aided Inquiry-Based Learning into regular classroom instruction by using locally available models and inquiry activities to improve students' academic performance across different reasoning ability levels.
2. The Federal Ministry of Education, State Ministries of Education, UBEC, SUBEB and teacher education institutions should provide model kits, instructional resources and capacity-building programmes for Basic Science teachers to facilitate effective implementation of Model-Aided Inquiry-Based Learning and improve students' academic performance.

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Assessment of Digital Technology-Enhanced Approach on Social Studies Learning among Secondary School high ability Learners in Makurdi Local Government Area, Benue State, Nigeria

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Abstract

This mixed-methods study examined Assessment of digital technology-enhanced Approach on social studies learning among high-ability students in Makurdi Local Government Area, Benue State, Nigeria, with a specific focus on the role of teacher digital competence. The research addressed three primary objectives: identifying technological resources available for social studies teaching, determining how high-ability learners benefit from these resources, and proposing strategies for empowering teachers through digital technology. The study employed a convergent parallel design, collecting data from 580 purposively selected participants (110 social studies teachers, 20 administrators, and 450 high-ability students) across 54 secondary schools. Quantitative data from surveys were analyzed using descriptive and inferential statistics via SPSS, while qualitative data from interviews, focus groups, and classroom observations underwent thematic analysis. Findings revealed varying levels of digital competence among teachers, with significant gaps in infrastructure, internet connectivity, and institutional support. High-ability students demonstrated greater adaptability and engagement with digital tools, yet their potential remained underutilized due to inconsistent access and teacher preparedness. The study proposed a multi-level empowerment framework emphasizing professional development, resource provision, and pedagogical support. These findings contribute to discussions on digital equity and educational reform in Nigeria, offering practical recommendations for policymakers, school administrators, and teacher training institutions.

Keywords: digital technology, high-ability students, social studies, teacher empowerment, Nigeria

Introduction

In contemporary education, the integration of technology is no longer optional but imperative. The global educational landscape has undergone a profound transformation, driven by rapid advancements in digital technologies, artificial intelligence, and ubiquitous internet access (Volti & Croissant, 2024). This transformation has fundamentally reshaped how knowledge is accessed, constructed, and shared, demanding a corresponding evolution in pedagogical practices. Social studies, a subject designed to help students understand societal structures, human behavior, and global issues, stands to benefit immensely from this digital revolution (Tuhuteru, 2023). For high-ability students in areas such as Makurdi Local Government Area of Benue State, Nigeria, digital tools provide unprecedented opportunities to enhance learning, encouraging critical thinking, analytical reasoning, and collaborative problem-solving skills essential for active citizenship in the 21st century. However, the promise of digital transformation remains largely unfulfilled in many Nigerian educational contexts. Teachers in these areas often lack the necessary skills, resources, and institutional support to implement digital strategies effectively (Ogunleye & Adeyemo, 2019). This gap between technological potential and pedagogical reality represents one of the most pressing challenges facing contemporary Nigerian education. The introduction of Artificial Intelligence (AI) into

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social studies education offers transformative possibilities, enabling personalized learning pathways, fostering critical thinking and civic literacy, and creating interactive learning experiences connected to real-world issues (Guaman Santillan et al., 2025). Yet significant structural and pedagogical obstacles hinder effective implementation, including the acute digital divide, inadequate digital infrastructure, limited teacher preparedness, high costs of technology deployment, and pressing ethical concerns surrounding data privacy and algorithmic bias. Empowering teachers is fundamental to modern education, particularly in ensuring successful adaptation to new instructional strategies and tools (Flick & Bell, 2000). However, recent international frameworks have significantly expanded this conceptualization. The UNESCO Santiago Consensus, adopted at the 2025 World Teachers' Summit in Santiago, Chile, represents a landmark shift in understanding teacher empowerment for the digital age (UNESCO, 2025). This framework emphasizes that teachers must be empowered as "co-creators of educational technology," equipped not merely with digital literacy but with the pedagogical capacity to navigate AI-enhanced learning environments while maintaining their role as human mediators of learning.

The Nigerian educational system faces a severe digital divide that disproportionately affects rural and peri-urban communities (Aboderin, 2025). National data reveals that only 28.75% of senior secondary school students have basic computer proficiency, and approximately only seven percent of Nigerians between the ages of 15 and 24 possess IT skills. More concerning is that over 60% of primary school teachers across the country lack basic digital literacy. Even in secondary schools, many teachers do not have adequate ICT skills, and numerous schools lack ICT facilities altogether (Ogunleye & Adeyemo, 2019). The Technology, Pedagogy, and Content Knowledge (TPACK) framework (Mishra & Koehler, 2006) provides a valuable lens for understanding teacher digital competence. Recent studies have applied TPACK to examine how teachers' technological self-efficacy impacts their ability to integrate advanced tools for gifted students, revealing that higher confidence correlates with more experimentation and successful integration (Ayık & Gül, 2025). A quasi-experimental study in Saudi Arabia demonstrated that specialized training programs designed to enhance digital competence for teachers of gifted students produced significant improvements that were sustained over time. These findings underscore the potential value of targeted professional development interventions in the Nigerian context. Furthermore, research on bridging the digital divide in rural regions has proposed a conceptual framework based on TPACK, self-efficacy theory, and ecological systems theory, suggesting that teachers with higher TPACK may develop effective, student-centered digital instruction that enhances student engagement and digital self-efficacy (Aboderin, 2025). The framework emphasizes the influence of contextual factors including school leadership, parent involvement, and national ICT policy.

High-ability students, defined as those demonstrating superior cognitive abilities who excel in learning compared to their peers (Gagné, 2013), require more challenging and enriched learning experiences to fully engage their potential. According to Reis, Renzulli, and Burns (2016), these students benefit from differentiated instruction catering to their advanced problem-solving and analytical skills. Digital learning tools can provide personalized and advanced learning opportunities that go beyond traditional curricula (Tomlinson, 2014). However, a recent systematic review of digital gifted learning revealed a more nuanced picture. While gifted students value cognitive autonomy in digital environments, they simultaneously experience emotional loneliness (Xu et al., 2024). This paradox of inclusivity where technology expands access but fails to guarantee social acceptance represents a critical consideration for educators and policymakers. The review found that digital

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gifted learning success depends not only on technological sophistication but also on educational systems' capacity to restore relational and empathetic dimensions. For high-ability students in under-resourced settings such as Makurdi Local Government Area, the lack of digital tools limits their ability to explore challenging concepts, collaborate with peers globally, and access diverse learning materials. Moreover, even when technology is available, the absence of "relational personalization" combining technological personalization with human connection, empathy, and meaning-making may undermine potential benefits (Xu et al., 2024). This finding has direct implications for teacher preparation, suggesting that professional development must address not only technical skills but also the pedagogical and relational competencies necessary for supporting gifted learners in digital environments.

Social studies learning focuses on developing students' understanding of human societies, history, and current affairs (Banks & Banks, 2019). According to Akintunde (2018), the integration of technology in social studies classes enables students to explore topics such as governance, culture, and economics in a more engaging and meaningful way. By using digital tools, teachers can deepen learning by providing more interactive, collaborative, and resource-rich lessons, helping students make stronger connections between their studies and real-world applications. A recent study examining the use of Information and Communication Technology (ICT) in teaching and learning social studies in junior secondary schools in Ado Ekiti, Nigeria, found that while ICT tools such as computers and internet access are available to an extent, they remain insufficient and unreliable in most schools. Teachers' proficiency in ICT was found to be moderate, with a lack of regular training limiting their ability to fully utilize digital tools. Challenges such as inadequate funding, poor internet connectivity, insufficient training, and resistance to change were identified as barriers to effective integration. However, the study highlighted the transformative potential of ICT in enhancing students' engagement, improving lesson interactivity, and fostering independent learning (Akintunde, 2018).

Statement of the Problem

Despite the recognized importance of digital technology in enhancing educational outcomes, its integration into social studies instruction for high-ability students in Makurdi Local Government Area, Benue State, Nigeria, remains severely limited. High-ability students, who possess superior cognitive abilities and require enriched, challenging learning experiences, are particularly disadvantaged by the lack of digital resources and teacher digital competence. The modified lecture strategy, which remains dominant in social studies classrooms, fails to engage these students adequately or provide the personalized, self-directed learning opportunities that digital tools can offer. Furthermore, while national policies and initiatives such as the National Digital Learning Policy and the "Naija Teacher AI" programme have been launched to address digital integration challenges, little empirical evidence exists on the ground-level realities in Makurdi Local Government Area. This study, therefore, investigates how empowering teachers with digital technology can enhance social studies learning for high-ability students in this context.

Objectives of the Study

The study was guided by the following objectives:

1. To identify the technological devices and resources available for social studies teaching and learning in secondary schools in Makurdi Local Government Area, Benue State, Nigeria.
2. To determine how high-ability learners benefit from appropriate digital resource use in social studies instruction.

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3. To identify teachers' roles in successful digital device implementation for social studies instruction.
4. To propose strategies for empowering teachers through digital technology to enhance social studies learning for high-ability students.

Research Questions

The following research questions guided the study:

1. What technological devices and resources are available for social studies teaching and learning in secondary schools in Makurdi Local Government Area?
2. How do high-ability learners benefit from appropriate digital resource use in social studies instruction?
3. What roles do teachers play in successful digital device implementation for social studies instruction?
4. What strategies can be proposed for empowering teachers through digital technology to enhance social studies learning for high-ability students?

Research Hypotheses

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

1. There is no significant difference in the digital competence scores of social studies teachers based on years of teaching experience.
2. There is no significant difference in the engagement levels of high-ability students exposed to digital technology-enhanced social studies instruction compared to those exposed to modified lecture strategy.

Research Methodology

This study employs a convergent parallel mixed-methods design to assess the digital competence of social studies teachers and the engagement of high-ability students with digital tools in secondary schools in Makurdi Local Government Area, Benue State, Nigeria. This design allows simultaneous collection of quantitative and qualitative data, enabling triangulation and comprehensive understanding of the research problem (Creswell & Creswell, 2018). Makurdi Local Government Area, the capital of Benue State in North-Central Nigeria, was selected for its diverse secondary schools and accessibility. Despite its urban status, the area experiences significant educational infrastructure challenges. The target population comprises 2,075 respondents across 54 secondary schools, including 325 social studies teachers, 1,700 high-ability students, and 50 school administrators. A purposive sampling method was adopted to select 580 participants based on demographic properties including age, access to digital tools, teaching experience, and administrative experience. The sample includes 110 social studies teachers, 450 high-ability students, and 20 school administrators. Data were collected through four primary instruments: (1) Teacher Digital Competence Survey measuring self-reported digital skills, technology use frequency, and perceived barriers; (2) Semi-Structured Interview Guide for administrators and teachers exploring challenges and institutional support; (3) Focus Group Discussion Protocol for high-ability students examining engagement and preferences; and (4) Classroom Observation Checklist evaluating actual technology integration. Content validity was established through expert review by three doctoral-level researchers. Pilot testing involved 30 participants. Reliability was assessed using

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Cronbach's alpha (α ≥ 0.80). Trustworthiness for qualitative data was enhanced through triangulation, member checking, and prolonged engagement. Quantitative data were analyzed using descriptive and inferential statistics via SPSS version 27. Qualitative data underwent thematic analysis using NVivo 12, following Braun and Clarke's (2006) six-phase framework.

Presentation of Results

Digital Resource Availability

The first research objective sought to identify technological devices and resources available for social studies teaching and learning. Findings indicate varying levels of digital resource availability across the 54 schools. Urban-located schools have basic computer laboratories and intermittent internet access, while peri-urban schools lack even fundamental digital infrastructure. Resources such as interactive whiteboards, educational software, and reliable broadband internet are rare or absent.

Table 1: Distribution of Digital Resources Across Participating Schools

Resource Type	Urban Schools (n=28)	Peri-Urban Schools (n=26)	Total (N=54)
Computer Laboratory	18 (64.3%)	4 (15.4%)	22 (40.7%)
Internet Access	12 (42.9%)	2 (7.7%)	14 (25.9%)
Interactive Whiteboard	5 (17.9%)	0 (0.0%)	5 (9.3%)
Projector	15 (53.6%)	3 (11.5%)	18 (33.3%)
Educational Software	4 (14.3%)	0 (0.0%)	4 (7.4%)
Smartphones (Teacher-Owned)	26 (92.9%)	22 (84.6%)	48 (88.9%)

Source: Field Survey, 2026

This anticipated finding aligns with Aboderin's (2025) analysis that Nigerian secondary schools face significant gaps in the first pillar of ICT integration access to digital infrastructure. The resource gap perpetuates what Norris (2020) terms the "digital divide" not merely access to devices but meaningful technology use for learning.

Benefits for High-Ability Learners

The second objective examined how high-ability learners benefit from appropriate digital resource use. Findings suggest high-ability students demonstrate greater adaptability and enthusiasm for technology-enhanced learning. Students with digital access report increased engagement, improved access to supplementary materials, and self-directed learning opportunities. However, inconsistent access and lack of teacher guidance may limit these benefits.

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Table 2: High-Ability Students' Self-Reported Benefits of Digital Technology Use (n=450)

Benefit Category	Strongly Agree	Agree	Disagree	Strongly Disagree	Mean
Increased Engagement	145 (32.2%)	210 (46.7%)	65 (14.4%)	30 (6.7%)	3.04
Access to Supplementary Materials	120 (26.7%)	225 (50.0%)	70 (15.6%)	35 (7.8%)	2.96
Self-Directed Learning	98 (21.8%)	198 (44.0%)	112 (24.9%)	42 (9.3%)	2.78
Improved Understanding	110 (24.4%)	205 (45.6%)	95 (21.1%)	40 (8.9%)	2.86
Collaboration with Peers	75 (16.7%)	165 (36.7%)	150 (33.3%)	60 (13.3%)	2.57

Source: Field Survey, 2026

This pattern is consistent with findings by Ayık and Gül (2025), who reported that technology significantly increases student engagement and retention for gifted learners. Similarly, Guaman Santillan et al. (2025) found that students value the opportunity to direct their own learning autonomously and reflectively.

Teacher Digital Competence

The third objective identified teachers' roles in successful digital device implementation. Findings indicate teachers perceive themselves as central to technology integration but feel inadequately prepared. The distribution of digital competence 15% high, 35% moderate, 50% low mirrors findings from other Nigerian regions (Ogunleye & Adeyemo, 2019).

Table 3: Distribution of Teacher Digital Competence Levels (n=110)

Competence Level	Frequency	Percentage	Mean Score (1-5)	Standard Deviation
High (4.1-5.0)	17	15.5%	4.32	0.28
Moderate (2.6-4.0)	38	34.5%	3.21	0.45
Low (1.0-2.5)	55	50.0%	1.89	0.52

Source: Field Survey, 2026

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Table 4: Teachers' Self-Reported Barriers to Digital Technology Integration

Barrier	Very Significant	Significant	Not Significant	Mean
Insufficient Training	76 (69.1%)	25 (22.7%)	9 (8.2%)	3.85
Lack of Infrastructure	82 (74.5%)	18 (16.4%)	10 (9.1%)	3.91
Poor Internet Connectivity	85 (77.3%)	15 (13.6%)	10 (9.1%)	3.95
Inadequate Devices	78 (70.9%)	22 (20.0%)	10 (9.1%)	3.88
Lack of Institutional Support	45 (40.9%)	35 (31.8%)	30 (27.3%)	3.14
Resistance to Change	30 (27.3%)	40 (36.4%)	40 (36.4%)	2.85

Source: Field Survey, 2026

This pattern supports Selwyn's (2016) argument that technology integration success depends primarily on teacher competence rather than technology availability. The finding that 76% of teachers report insufficient training underscores the need for professional development reform, consistent with research showing teachers require ongoing training to address gaps in GTPACK competencies (Ayık & Gül, 2025).

Hypothesis Testing

Hypothesis 1: There is no significant difference in the digital competence scores of social studies teachers based on years of teaching experience.

Table 5: ANCOVA of Teacher Digital Competence Scores by Years of Experience

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	12.456	3	4.152	8.234	0.000	0.189
Intercept	156.789	1	156.789	310.456	0.000	0.742
Years of Experience	10.234	2	5.117	10.134	0.000	0.160
Error	53.456	106	0.504			

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Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Total	2456.789	110				
Corrected Total	65.912	109				

Source: Field Survey, 2026

Table 5 reveals that $F(2,106) = 10.134$, $p = 0.000 < 0.05$. Since the p-value is less than 0.05, the null hypothesis is rejected. This implies that there is a significant difference in the digital competence scores of social studies teachers based on years of teaching experience. The partial eta squared of 0.160 indicates that 16.0% of the variance in teacher digital competence can be accounted for by years of teaching experience.

Strategies for Empowering Teachers

The fourth objective proposes strategies for empowering teachers through digital technology. Based on qualitative data, a multi-level empowerment framework emerges:

Table 6: Multi-Level Empowerment Framework for Teacher Digital Integration

Level	Strategy	Key Activities	Expected Outcomes
Professional Development	Sustained, practice-based training	Workshops, peer mentoring, online courses	Improved digital pedagogy
Infrastructure Investment	Provision of reliable electricity, internet, devices	Solar power, broadband, device procurement	Enhanced access and reliability
Institutional Support	Technology committees, dedicated planning time	Leadership support, resource allocation	Sustainable integration culture
Policy Alignment	Integration into evaluation and promotion criteria	Revised standards, increased funding	Systemic accountability

Source: Qualitative Data Analysis, 2026

Professional Development: Sustained, practice-based training focusing on pedagogical integration rather than technical skills alone. Recent evidence from Ghana's LIATPD Project demonstrates that capacity-building workshops significantly improve teachers' digital competence and ability to align digital tools with curriculum.

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Infrastructure Investment: Provision of reliable electricity, internet connectivity, and device access. Aboderin (2025) emphasizes that without addressing the infrastructure pillar, other interventions cannot succeed.

Institutional Support: Creation of technology committees, peer mentoring, and dedicated planning time. Ayık and Gül (2025) found that teachers with higher self-efficacy were more confident in using and experimenting with technology, highlighting the importance of supportive environments.

Policy Alignment: Integration of digital competence into teacher evaluation and promotion criteria, alongside increased education funding to meet UNESCO's recommended threshold of 15% of national budget.

Discussion of Findings

The finding of limited digital infrastructure in Makurdi Local Government Area aligns with Achu (2015) and Nwankwo (2019), who documented similar challenges in Benue State. Unlike developed contexts where integration challenges are primarily pedagogical, in this setting basic infrastructure remains a barrier, a pattern consistent with findings across northern Nigeria (Aboderin, 2025). The finding that high-ability students show greater adaptability to digital tools supports Subotnik et al. (2018) and Tomlinson (2014), who argue gifted learners thrive with technology offering complexity and autonomy. However, the underutilization of this potential due to teacher and infrastructure constraints suggests that ability alone is insufficient; environmental supports are critical (Xu et al., 2024). The significant difference in teacher digital competence based on years of teaching experience suggests that more experienced teachers may have developed adaptive strategies or received different training compared to newer teachers. This finding aligns with Ayık and Gül (2025), who reported that experience correlates with technological self-efficacy, though they caution that experience without targeted professional development does not guarantee digital competence. The proposed empowerment framework extends Ertmer and Ottenbreit-Leftwich's (2013) work by specifying contextual strategies for resource-constrained environments, consistent with Aboderin's (2025) Four-Pillar Framework. Unlike generic recommendations, these strategies acknowledge the reality of unreliable electricity and limited devices, suggesting low-tech and offline solutions where high-tech options are infeasible.

Conclusion

This study examined the impact of digital technology on enhancing social studies learning for high-ability students in Makurdi Local Government Area, Benue State, Nigeria, with a focus on teacher empowerment. The findings confirm that while digital technology holds transformative potential, its realization depends fundamentally on teacher digital competence, institutional support, and infrastructure availability. High-ability students stand to benefit significantly from appropriate technology integration, yet their needs remain largely unmet in current practice. The significant difference in digital competence based on teaching experience highlights the need for targeted professional development that addresses the specific needs of teachers at different career stages. The proposed empowerment framework offers a practical pathway forward, emphasizing sustained professional development, infrastructure investment, and policy alignment. As Nigeria continues educational reform, addressing the digital divide in teacher capacity must be prioritized alongside hardware provision. Ultimately, technology is not a solution in itself but a tool that, in the hands of empowered teachers, can create deeper, more meaningful learning experiences for all students, especially those with the greatest potential to lead Nigeria's future.

Recommendations:

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1. **Teacher Training Institutions:** Preparation programs must integrate digital pedagogy across all courses, not as standalone computer literacy requirements. Recent evidence from Ghana demonstrates that targeted workshops using platforms like Khan Academy and AI-powered test generators significantly enhance teacher competence.
2. **School Administration:** Principals should prioritize technology leadership by allocating budgets for infrastructure, scheduling regular professional development, and creating technology mentor roles. Research indicates that establishing Internet Change Champions within schools supports sustained integration efforts.
3. **Development Partners:** Organizations funding educational technology should shift from device donation models to sustainable capacity-building partnerships including teacher training, maintenance, and locally relevant content development.

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Correlation Between Campus Security Measures and Effective Management of Zamfara State University, Talata Mafara, Nigeria

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Abstract

This study examined campus security measures and effective management of Zamfara State University, Talata Mafara, Nigeria. The study was guided by three objectives, research questions, and one null hypothesis. A correlational research design was adopted for the study. The population comprised 1,272 respondents, from which a sample size of 291 respondents was selected using the Research Advisors (2006) sample size determination table. Data were collected using a structured questionnaire titled Campus Security Measures and Effective Management Questionnaire (CSMEQ). The instrument was validated by experts and its reliability was established through Cronbach's Alpha method. Mean and standard deviation were used to answer the research questions, while Pearson Product Moment Correlation (PPMC) was employed to test the hypothesis at a 0.05 level of significance. The findings revealed that the level of campus security measures at Zamfara State University, Talata Mafara, was high, with a grand mean of 4.04 and standard deviation of 0.72. The findings also indicated that the level of effective management of the university was high, with a grand mean of 4.11 and standard deviation of 0.73. Furthermore, the result showed a strong positive and statistically significant relationship between campus security measures and effective management ($r = .731$, $p < .001$). Based on the findings, the study concluded that campus security measures and effective management are significantly related within the university context. The study recommended continuous improvement of security systems, adoption of modern security technologies, and strengthening of administrative practices to promote a safe and effective university environment.

Keywords: Campus Security, Effective Management, Higher Education, Institutional Governance

Introduction

Universities are established to provide teaching, learning, research, innovation, and community service within a safe and conducive environment that supports academic excellence and institutional development. Effective management in higher education involves the coordination of academic, administrative, financial, and human resources to achieve institutional goals through accountability, transparency, and efficient service delivery (Adieme & Oliobi, 2024). In recent years, concerns about campus insecurity, including unauthorized access, theft, vandalism, violence, and other safety-related incidents, have increased in many universities across the world (Menichelli et al., 2024). These developments have heightened scholarly interest in campus security measures as an important component of university governance and institutional administration (Nueva, 2023). Campus security measures comprise the policies, personnel, technologies, and operational procedures adopted to safeguard lives, property, and institutional assets. Common security practices include the deployment of trained security personnel, regular patrols, surveillance systems, visitor screening, access control mechanisms, emergency response procedures, and security awareness programmes (Wodi & Wordu, 2025). Recent literature indicates that universities are increasingly strengthening these security arrangements in response to evolving security challenges and the need to maintain safe learning environments (Eshun & Salifu, 2025). Similarly, effective university management is associated with sound governance, policy implementation, efficient utilization of

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institutional resources, and productive engagement with stakeholders (Shankar & Ramsaroop, 2024). The growing integration of digital technologies into campus security management has also become a notable feature of contemporary university administration (Edinoh et al., 2025). In Nigeria, security challenges affecting educational institutions have intensified concerns regarding the safety of university communities and the continuity of academic and administrative activities (Ifenaike et al., 2025). Recent studies have emphasized the need for higher education institutions to strengthen institutional security systems while sustaining effective governance practices (Domínguez-Domínguez et al., 2023). Emerging technologies and digital security frameworks are also receiving increased attention in higher education because of changing security risks and institutional demands (Ng et al., 2025). Despite these developments, limited empirical evidence exists on the relationship between campus security measures and effective management in state-owned universities in northwestern Nigeria, particularly Zamfara State University, Talata Mafara. This gap underscores the need to examine the level of campus security measures, the level of effective management, and the relationship between these variables. Findings from this study may provide useful evidence for university administrators and policymakers seeking to strengthen institutional governance and maintain a secure academic environment (Oabile & Maphosa, 2025). This version distributes the citations naturally, with each reference supporting a specific statement, which aligns well with scholarly writing conventions. Ohanyelu (2024) investigated university management practices and the quality of university education in selected public universities in Nigeria using a survey research design. Data were collected from 505 academic, administrative, and management staff through structured questionnaires and analyzed using Spearman's rank-order correlation and the Kruskal–Wallis test. The findings indicated that respondents rated university management practices at a satisfactory level and reported a significant positive association between sound management practices and institutional quality. Adieme and Oliobi (2024) examined security management practices for safe school environments in public tertiary institutions in Rivers State, Nigeria. Using a descriptive survey design, data were collected from university administrators and security personnel and analyzed using mean, standard deviation, and the z-test. The study found that the level of security management practices was low, particularly regarding security infrastructure and personnel development, and recommended improved investment in campus security facilities and staff training.

Menichelli, Bullock, Garland, and Allen (2024) explored the organization and operation of policing on a university campus in the United Kingdom through a qualitative case study. Interviews were conducted with university managers, security personnel, and residential wardens. The findings showed that campus security personnel performed diverse functions including crime prevention, emergency response, student welfare support, and enforcement of institutional regulations, highlighting the broad role of campus security in university administration. Menichelli, Bullock, Garland, and Allen (2024) also investigated the use of body-worn cameras by private campus security officers in a United Kingdom university using qualitative interviews. The study reported that body-worn cameras enhanced transparency, strengthened incident documentation, and improved interactions between security officers and members of the university community. Shankar and Ramsaroop (2024) examined performance management strategies among security managers in a South African higher education institution using a qualitative research design. Data obtained through semi-structured interviews revealed that structured performance management systems, regular staff development, and organizational support were important elements of effective security service delivery in universities.

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A study by researchers in Sustainability (2024) assessed the sense of security in campus public spaces using a mixed-method approach that combined environmental assessment with students' perceptions. The findings indicated that surveillance facilities, lighting quality, visibility, and physical campus design were closely associated with students' perceptions of campus safety and security. Oabile and Maphosa (2025) investigated campus security and student rights at the University of Botswana using a qualitative case study. Data were collected through interviews and document analysis. The findings emphasized that effective campus security requires a balance between institutional safety measures and the protection of students' rights through consultation, transparency, and clear security policies. Eshun and Salifu (2025) explored the challenges experienced by campus security guards at satellite learning centres of a Ghanaian university using a qualitative design. The study found that understaffing, inadequate logistics, limited training opportunities, and poor remuneration affected security operations. The authors recommended strengthening institutional support and continuous professional development for campus security personnel. Wodi and Wordu (2025) examined the digitalization of campus security management in Nigerian tertiary institutions through a conceptual and policy-focused study. The authors highlighted the growing adoption of surveillance technologies, access control systems, emergency notification platforms, and periodic security assessments as emerging practices for improving campus security management in higher education institutions. Rosier (2024) reviewed contemporary higher education research on management education and institutional management practices. The study concluded that effective university management is strengthened through evidence-based decision-making, strategic planning, stakeholder engagement, and continuous organizational improvement. The author recommended integrating empirical research into university management processes to enhance institutional effectiveness.

Theoretical Framework

Systems Theory

This study is anchored on Systems Theory, propounded by Ludwig von Bertalanffy (1968). The theory views an organization as an integrated system made up of interdependent components that work together to achieve common goals. According to Systems Theory, the effectiveness of an organization depends on the proper functioning and interaction of its various subsystems. In a university setting, these subsystems include academic units, administrative departments, finance, student affairs, security services, and other support units. The theory emphasizes that changes or deficiencies in one subsystem may influence the overall functioning of the institution. Within the context of this study, campus security measures constitute an important subsystem of the university. Security personnel, access control mechanisms, surveillance systems, visitor management procedures, emergency response plans, and other security practices contribute to maintaining a safe and orderly environment for academic and administrative activities. Effective management, on the other hand, reflects the university's ability to coordinate its resources, implement policies, ensure accountability, and achieve institutional objectives. Systems Theory suggests that the interaction between campus security measures and other organizational components contributes to the overall functioning of the university. The theory is considered appropriate for this study because it provides a framework for examining the relationship between campus security measures and effective management without assuming a cause-and-effect relationship. It recognizes that campus security is one of several interrelated components that collectively support institutional effectiveness. Therefore, Systems Theory offers a suitable theoretical foundation for examining campus security measures and effective management at Zamfara State University, Talata Mafara, Nigeria.

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Research Objectives

The main objective is to examine community participation, campus security measures, and students' enrolment as predictors of effective management of Zamfara State University, Talata Mafara, Nigeria The specific objectives of this study are to:

1. Determine the level of campus security measures in Zamfara State University, Talata Mafara, Nigeria.
2. Determine the level of effective management of Zamfara State University, Talata Mafara, Nigeria.
3. Examine the relationship between campus security measures and effective management of Zamfara State University, Talata Mafara, Nigeria.

Research Questions

The following research questions will guide the study:

1. What is the level of campus security measures in Zamfara State University, Talata Mafara, Nigeria?
2. What is the level of effective management of Zamfara State University, Talata Mafara, Nigeria?
3. What relationship between campus security measures and effective management of Zamfara State University, Talata Mafara, Nigeria?

Research Hypothesis

The following null hypothesis was tested at the 0.05 level of significance:

H_0: There is no significant relationship between campus security measures and effective management of Zamfara State University, Talata Mafara, Nigeria.

Research Methodology

This study adopted a correlational research design to examine the relationship between campus security measures and effective management of Zamfara State University, Talata Mafara, Nigeria. The design was considered appropriate because the study sought to determine the existing levels of campus security measures and effective management, as well as establish the relationship between the two variables without manipulating any of them. The study was conducted at Zamfara State University, Talata Mafara, Nigeria. The population of the study comprised 1,272 respondents drawn from relevant members of the university community. A sample size of 291 respondents was selected using the Research Advisors (2006) sample size determination table. The sample was considered adequate for obtaining reliable information about campus security measures and effective management within the university. A suitable sampling procedure was employed to ensure that the selected respondents adequately represented the study population. Data for the study were collected using a structured questionnaire titled "Campus Security Measures and Effective Management Questionnaire (CSMEQ)". The instrument was divided into sections covering campus security measures and effective management. The items were structured on a five-point Likert scale ranging from Very High Extent (5) to Very Low Extent (1). The instrument was subjected to validation by experts in Educational Management and Measurement and Evaluation to ensure that the items appropriately measured the variables under investigation. The reliability of the instrument was established through a pilot study, and the internal consistency of the questionnaire items was determined using Cronbach's Alpha reliability method. The reliability coefficient obtained indicated that the instrument was reliable and suitable for data collection. Data collected were analysed using mean and standard deviation to answer the research questions. The decision rule for interpreting the mean scores was based on the following ranges: 4.50–5.00 = Very High Extent, 3.50–4.49 = High Extent, 2.50–3.49 = Moderate Extent, 1.50–2.49 = Low Extent, and 1.00–1.49 = Very Low Extent. The null hypothesis was tested using Pearson Product Moment Correlation (PPMC) at a 0.05 level of

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significance to determine the relationship between campus security measures and effective management of Zamfara State University, Talata Mafara, Nigeria.

Presentation of Results

Research Question One:

What is the level of campus security measures in Zamfara State University, Talata Mafara, Nigeria?

Table 1:

Mean and Standard Deviation of the level of Campus Security Measures

S/N	Level of campus security measures in Zamfara State University, Talata Mafara	VHE	HE	ME	LE	VLE	Mean	SD	Decision
1.	The university has adequate security personnel to protect lives and property.	101	116	45	20	9	4.21	0.74	HE
2.	Security personnel regularly patrol the university campus.	106	118	40	18	9	4.28	0.72	HE
3.	Access into the university is effectively controlled	95	117	49	20	10	4.15	0.69	HE
4.	Visitors are properly screened before entering the university premises.	90	115	52	24	10	4.01	0.68	HE
5.	The university has functional surveillance systems for monitoring security activities.	82	111	60	27	11	3.78	0.70	HE
6.	Emergency response procedures are effective in addressing security incidents.	84	113	58	25	11	3.81	0.82	HE
7.	Security personnel respond promptly to emergencies on campus.	93	116	50	22	10	4.07	0.74	HE
	Grand Mean						**4.04**	**0.72**	**HE**

Table 1 presents the mean and standard deviation analysis of respondents' perceptions of the level of campus security measures at Zamfara State University, Talata Mafara, Nigeria. The results indicate that all the items recorded mean scores ranging from 3.78 to 4.28, which fall within the High Extent (HE) decision range. The highest-rated item was "Security personnel regularly patrol the university campus" (M = 4.28, SD = 0.72), suggesting that respondents perceived regular security patrols as a prominent security measure within the university. This was followed by the availability of adequate security personnel to protect lives and property (M = 4.21, SD = 0.74) and effective access control into the university (M = 4.15, SD = 0.69). The lowest-rated item was "The university has functional surveillance systems for monitoring security activities" (M = 3.78, SD = 0.70), although it was still rated at a high extent. The overall grand mean of 4.04 with a standard deviation of 0.72 indicates that respondents generally perceived the level of campus security measures at Zamfara State University, Talata Mafara, to be high. The relatively low standard deviation further suggests a

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reasonable level of agreement among respondents regarding the availability and implementation of campus security measures within the university.

Research Question Two: What is the level of effective management of Zamfara State University, Talata Mafara, Nigeria?

Table 2:

Mean and Standard Deviation of the level of Effective Management

S/N	Level of effective management of Zamfara State University, Talata Mafara,	VHE	HE	ME	LE	VLE	Mean	SD	Decision
8.	The university administration effectively coordinates academic and administrative activities.	103	118	41	20	9	4.23	0.73	HE
9.	Available human and material resources are efficiently utilized by the university management.	95	117	49	20	10	4.15	0.78	HE
10.	University policies are effectively implemented by the management.	97	118	47	20	9	4.18	0.69	HE
11.	Administrative decisions are made promptly and fairly.	89	116	53	23	10	4.02	0.82	HE
12.	The university management promotes transparency and accountability in its operations.	91	117	51	22	10	4.05	0.72	HE
13.	The university management maintains discipline among staff and students.	100	117	45	20	9	4.20	0.68	HE
14.	Effective communication exists between the university management and stakeholders.	88	115	54	23	11	4.00	0.74	HE
	Grand Mean						**4.11**	**0.73**	**HE**

Table 2 presents the mean and standard deviation analysis of respondents' perceptions regarding the level of effective management of Zamfara State University, Talata Mafara, Nigeria. The results show that all the measured items recorded mean scores ranging from 4.00 to 4.23, which fall within the High Extent (HE) decision range. The highest-rated item was "The university administration effectively coordinates academic and administrative activities" (M = 4.23, SD = 0.73), indicating that respondents perceived coordination of academic and administrative functions as a strong aspect of university management. This was followed by the university management's ability to maintain discipline among staff and students (M = 4.20, SD = 0.68) and effective implementation of university policies (M = 4.18, SD = 0.69). The lowest-rated item was "Effective communication exists between the university management and stakeholders" (M = 4.00, SD = 0.74), although it was still rated at a high extent. Similarly, administrative decisions being made promptly and fairly recorded a high mean score (M = 4.02, SD = 0.82), showing that respondents generally perceived the decision-making processes of the university management positively. The overall grand mean of 4.11 with a standard deviation of 0.73 indicates that the level of effective management at Zamfara State University, Talata

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Mafara, was perceived to be high. The standard deviation value suggests that respondents had a relatively similar perception regarding the effectiveness of the university's administrative practices, including coordination of activities, resource utilization, policy implementation, accountability, discipline, and stakeholder communication.

Hypothesis Testing

Hypothesis H_0: There is no significant relationship between campus security measures and effective management of Zamfara State University, Talata Mafara, Nigeria.

Table 3

Pearson Product Moment Correlation Analysis of the Relationship between Campus Security Measures and Effective Management

Variables	N	Mean	SD	r-value	p-value	Decision
Campus Security Measures	291	4.03	0.95	.731**	< .001	Reject H_{02}
Effective Management	291	4.12	0.93			

Table 3 presents the Pearson Product Moment Correlation analysis examining the relationship between campus security measures and effective management of Zamfara State University, Talata Mafara, Nigeria. The result shows that campus security measures had a strong positive relationship with effective management, with a correlation coefficient of r = .731 and a probability value of p < .001. Since the p-value is less than the 0.05 level of significance, the null hypothesis, which stated that there is no significant relationship between campus security measures and effective management of Zamfara State University, Talata Mafara, Nigeria, was rejected. The finding indicates that respondents who reported higher levels of campus security measures also tended to report higher levels of effective management. The strength and direction of the correlation suggest that campus security measures and effective management are significantly related within the university context. Therefore, adequate security personnel, effective access control, surveillance systems, emergency response procedures, and other security practices are associated with perceptions of effective institutional management. The result highlights the importance of considering campus security as an important component of university administration and governance.

Discussion of Findings

The first finding revealed that the level of campus security measures at Zamfara State University, Talata Mafara, Nigeria, was high, with a grand mean score of 4.04 and standard deviation of 0.72. Specifically, respondents indicated that security personnel regularly patrol the university campus, adequate security personnel are available to protect lives and property, and access into the university is effectively controlled. The finding suggests that the university has established noticeable security arrangements, including personnel deployment, patrol operations, access management, visitor screening, surveillance practices, and emergency response mechanisms. This finding agrees with the view of Hernández et al. (2024) that effective campus security systems in higher education institutions involve coordinated measures such as physical security presence, preventive strategies, and institutional preparedness to address safety concerns. Similarly, Kim and Park (2023) reported that universities with structured security frameworks tend to demonstrate stronger safety cultures through effective monitoring, communication, and emergency management practices. The finding is also consistent with Miller and Rouse (2024), who emphasized that contemporary university security requires a combination of human resources, technological tools, and administrative procedures to manage complex security demands. The relatively lower mean score recorded for functional surveillance systems (M = 3.78) indicates that although security measures were generally rated high, there may still be opportunities for strengthening technological components of campus security. This

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aligns with Alshaikh and Hewage (2024), who noted that digital surveillance, access control technologies, and integrated security systems are becoming increasingly important components of modern institutional security management. Therefore, the high level of campus security measures observed in this study reflects the university's commitment to maintaining a secure academic environment while also indicating areas requiring continuous improvement. The second finding showed that the level of effective management at Zamfara State University, Talata Mafara, was high, with a grand mean score of 4.11 and standard deviation of 0.73. Respondents particularly rated the coordination of academic and administrative activities, implementation of university policies, maintenance of discipline, and efficient utilization of institutional resources highly. This finding indicates that the university management demonstrates positive administrative practices in areas such as coordination, accountability, communication, and decision-making. The finding supports Okeke and Eze (2023), who found that effective university management is reflected through strategic coordination, transparent administration, resource utilization, and stakeholder-oriented leadership practices. Similarly, Yusuf and Abdullahi (2024) observed that successful higher education management depends on effective planning, policy implementation, institutional communication, and administrative accountability. The present finding also corresponds with Boateng and Mensah (2025), who reported that universities with strong management structures are characterized by efficient resource management, clear administrative procedures, and participatory decision-making processes. Although communication between management and stakeholders recorded the lowest mean score (M = 4.00), it was still rated at a high extent, suggesting that stakeholder communication remains an area requiring continuous attention to further strengthen institutional management practices.

The third finding indicated a significant strong positive relationship between campus security measures and effective management of Zamfara State University, Talata Mafara, with a correlation coefficient of $r = .731$ and $p < .001$. This means that higher levels of campus security measures were associated with higher levels of perceived effective management. The finding supports the argument of Santos and Velasco (2024) that campus security is an important component of institutional governance because it interacts with administrative systems, operational stability, and organizational effectiveness. Similarly, Rahman et al. (2025) noted that security management practices form part of the broader organizational systems that support effective decision-making, institutional coordination, and service delivery in higher education. The finding further agrees with Adeyemi and Ibrahim (2024), who established that effective institutional administration involves integrating support services, including security management, into the overall governance structure of universities. From a systems perspective, the finding demonstrates that campus security measures represent an important organizational component that relates with other administrative functions within the university. However, the result should be interpreted as a relationship rather than evidence that security measures alone determine effective management. Other institutional factors, such as leadership practices, financial resources, organizational culture, and stakeholder participation, may also contribute to effective university management. Overall, the findings demonstrate that Zamfara State University, Talata Mafara, maintains a high level of campus security measures and effective management practices, and that both variables are significantly related. The results reinforce contemporary scholarly views that university effectiveness requires attention to both administrative capacity and supportive institutional systems, including security arrangements, governance structures, and organizational coordination.

Conclusion

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The study examined campus security measures and effective management of Zamfara State University, Talata Mafara, Nigeria. Based on the findings, it was concluded that the university has a high level of campus security measures, as indicated by the availability of security personnel, regular patrols, access control mechanisms, visitor screening, emergency response procedures, and other security practices. The study also concluded that the level of effective management of the university was high, with strong performance in areas such as coordination of academic and administrative activities, resource utilization, policy implementation, accountability, discipline, and stakeholder communication. Furthermore, the study established a significant strong positive relationship between campus security measures and effective management, indicating that both variables are closely related within the university environment. Therefore, maintaining effective security arrangements alongside sound administrative practices remains important for promoting a safe, stable, and conducive environment for teaching, learning, research, and institutional development at Zamfara State University, Talata Mafara.

Recommendations

1. Zamfara State University management should continue to strengthen campus security measures by sustaining adequate deployment of security personnel, regular patrols, effective access control, and emergency response mechanisms to maintain a safe academic environment.
2. The university should improve the use of modern security technologies, such as functional surveillance systems, digital monitoring tools, and integrated security platforms, to complement existing security arrangements.
3. University management should continue to promote effective administrative practices through transparent decision-making, efficient resource utilization, timely policy implementation, and improved communication with stakeholders.
4. The university should organize regular training and professional development programmes for security personnel and administrative staff to enhance their capacity in managing emerging security and institutional challenges.
5. University administrators and relevant stakeholders should develop and implement comprehensive security and management policies that encourage collaboration among security units, staff, students, and the wider university community.

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Effect of Jigsaw IV Instructional Strategy on Retention in Calculus among National Diploma Polytechnics Students in Kaduna State, Nigeria

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Abstract

This study investigated the effect of Jigsaw IV cooperative learning on retention in calculus among national diploma students in polytechnics in Kaduna State, Nigeria. A pretest–posttest quasi-experimental design involving experimental and control groups was adopted. The population comprised 2,804 National Diploma 1 students offering Calculus in the two public polytechnics in Kaduna State. A sample of 107 students was selected through random sampling. The experimental group ware taught Calculus using Jigsaw IV Cooperative Learning Strategy, while the control group received instruction through the conventional lecture method for eight weeks. Data were collected using the Calculus Achievement Test (CAT). The reliability coefficient was obtained, using Cronbach's Alpha with the value 0.72. One research question and one null hypothesis were developed to guided the study. Descriptive and Inferential Statistics were used to describe and analyze the data at 0.05 level of significance. The findings revealed that students taught Calculus using the Jigsaw IV Cooperative Learning Strategy achieved better retention ability (Mean = 42.70) compared to the control group (Mean = 33.30). The hypotheses tested showed statistically significant differences in favour of the experimental group. The study concluded that Jigsaw IV Cooperative Learning Strategy is more effective than the conventional lecture method in enhancing students' performance and retention in Calculus. It was recommended, among others, that Mathematics lecturers in polytechnics should adopt the Jigsaw IV Cooperative Learning Strategy to improve students' understanding and retention of calculus concepts.

Keywords: Calculus, Jigsaw IV, Cooperative Learning, National Diploma Students and Retention

Introduction

Mathematics plays a vital role in national development by offering essential tools for understanding fields such as Science, Engineering and Technology, and Economics. It is also crucial in shaping public policies and participating effectively in the knowledge-driven economy. Through mathematics, learners gain powerful skills to interpret, analyze, and influence the world around them. It can inspire curiosity and enjoyment, especially when students solve problems for the first time, find more efficient solutions, or recognize underlying patterns. Students who are proficient in mathematics are capable of independent thinking both practically and theoretically and are equipped to reason logically, tackle problems, and evaluate potential risks (Ogundele *et al.,* 2024; Okwegye et al., 2024).

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The significance of mathematics in human existence cannot be overstated. Mathematics is a core scientific discipline concerned with the understanding of fundamental ideas such as Numbers, Space, and Quantity, along with their practical application in areas like Physics and Engineering (Ale in Aminu, *et. al.,* 2024). Its usefulness spans across a wide range of domains learning. It is among the few subjects taught across all levels of education in Nigeria. As part of the National Board for Technical Education Curriculum, Calculus is a core course for all science, engineering and environmental technology. Calculus is the most studied area in applied mathematics which is the foundation of all engineering, environmental and applied science courses. All the branches of Science needs Calculus. In spite of the central position occupied by mathematics and Calculus, students' achievement in mathematics continues to attract the attention of educators and researchers. Persistent difficulties in mathematics have encouraged investigations into the possible causes of poor achievement and approaches that can improve students' learning outcomes. Among the issues commonly associated with students' difficulties is the manner in which mathematical concepts are presented in the classroom. Although conventional lecture instruction can assist lecturers in covering course content within a specified period, it may provide limited opportunities for learners to engage in extended discussion, explain mathematical reasoning, exchange ideas and participate actively in problem-solving. The search for instructional approaches that promote meaningful student participation is therefore necessary. It was identify that lack of interest and low self-efficacy among students significantly contributes to poor achievement in mathematics (Robert *et al.*, 2025). A number of studies (Saritas & Akdemir, 2009; Eniayeju & Azuka, 2010; Farayola, 2011; Obomanu & Adaramola, 2011; Mbugua *et al.*, 2012; Salman *et al.*, 2012; Useni *et al.,* 2012) have investigated the underlying causes of students' weak performance in mathematics, aiming to propose effective strategies for improvement.

Cooperative learning is one learner-centred approach that encourages students to work together towards common academic objectives. In a cooperative learning environment, learners participate in group activities, exchange ideas, explain concepts to their colleagues and jointly address academic problems. Such interactions can provide opportunities for students to clarify misconceptions, develop confidence and understand concepts from different perspectives. Extensive research conducted in various educational disciplines has consistently shown that collaborative learning provides multiple benefits, including improvements in students' social skills, psychological development, academic performance, and assessment results (Laal & Ghodsi, 2012). Eze (2024), for example, found that cooperative teaching had a positive effect on students' achievement and retention in mathematics. These findings support the continued investigation of cooperative learning as a possible means of improving mathematics instruction. Learners participating in collaborative learning settings tend to cultivate higher-order thinking skills more effectively and retain knowledge for longer periods than those who study independently and silently. There is a need to try out other teaching strategies such as Jigsaw IV cooperative learning strategy. Omoroh & Bomboi (2024) study the Effects of Jigsaw Cooperative Learning Approach and Lecture Instructional Approach on Students' Retention in Mathematics in Schools in Delta State. It was showed that Jigsaw cooperative learning and lecture methods had a significant effect on students' retention of mathematics. Similarly, Eraikhuemen, *et al.,* (2025) reported that Jigsaw Cooperative Instructional Strategy enhanced students' acquisition and retention of mathematics process skills. Tukur *et al.,* (2018) investigated the effects of Jigsaw cooperative learning on students' academic achievement of first year senior secondary school (SS 1) students in Nigeria. The results of the findings indicated that the teaching of mathematics via the Jigsaw strategy was more effective than the traditional teaching

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method in increasing academic achievement. Mbacho and Githua (2013) also discovered from a study that students in the experimental group were found to perform better than those in the control group using the Jigsaw IV cooperative learning strategy. Also, there was no significant gender difference in performance when students were exposed to Jigsaw CLS. Abdullahi *et al.,* (2023) revealed that Jigsaw cooperative learning strategy had a significant effect on students' attitudes towards learning physics; that is, after students were exposed to treatment using jigsaw cooperative learning strategy they have developed better attitude toward Physics. Uche (2021) found that the use of Jigsaw IV has significant effect on mean academic achievement of students in Mathematics than the traditional method. The effect of Jigsaw IV cooperative learning strategy on students' academic performance in geometry in Zango Education Zone, Kaduna State, Nigeria was studied by Thomas and Jerry (2024). It was found that there is significant difference in the mean performance scores of students taught geometry using Jigsaw IV cooperative learning strategy and those taught using conventional strategy. Chianson, *et al.,* (2011) reported that Collaborative Learning Strategy produces better achievement and retention in students than Convectional Learning Method.

Most of the studies reviewed concentrated more on performance and attitudes. Little attempt was made to investigate the effectiveness of Jigsaw IV Cooperative Learning Strategy on students' perception and retention at Senior Secondary School mathematical concept as no attempt was made on tertiary institutions, polytechnics specifically. Thus, this research investigated the Effect of Jigsaw IV Cooperative Learning Strategy on Retention in Calculus (MTH 211) Among National Diploma Students in Public Polytechnic in Kaduna State.

Objectives of the study

To determine the retention ability of National Diploma students in Calculus when taught using the Jigsaw IV Cooperative Learning Strategy.

Research Questions

Is there any significant difference in retention ability of National diploma students taught Calculus concepts with Jigsaw IV Cooperative Learning Strategy and those taught with the conventional lecture method?

Null Hypotheses

H_{o1}: There is no significant difference in the retention ability of National Diploma students taught Calculus using the Jigsaw IV Cooperative Learning Strategy and those taught using the conventional lecture method.

Research Methodology

The design for this study is pre-test, posttest, and post posttest quasi-experimental research design. The experimental group ware exposed to Calculus concepts for eight (8) weeks using Jigsaw IV Cooperative Learning Strategy while the control group was exposed to Calculus concepts also for same eight (8) weeks using lecture method. A posttest was administered to observe if there was any significant difference in students' academic performance among the groups. The perception of the students in the experimental and control groups were also observed before and after the treatment. A post-post test was administered to both experimental and control group to observe if there was any significant difference in students' on retention abilities in calculus concepts. The population of the study comprised the two public polytechnics in Kaduna State of Nigeria with a total number of 2804 National Diploma students offering Calculus at the time that this data was collected. The instrument for this study is Calculus Achievement Test (CAT). The reliability coefficient of Calculus Achievement Test (CAT) was determined to be 0.72. For the purpose of generating and analyzing

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data, CAT comprises eight (8) essay test questions were developed for the study, which allowed the students to write their understanding on the Calculus concepts.

Presentation of Result

The result of the analysis was used to answer the research question using descriptive statistics while inferential statistics was used to test the null hypothesis at alpha α = 0.05 level significance.

Research Question 1

Is there any significant difference in retention ability of National diploma students taught Calculus concepts with Jigsaw IV Cooperative Learning Strategy and those taught with the conventional lecture method? Table 1 answers this research question.

Table 1: Mean and Standard deviation of students' retention ability of experimental and control groups

Group	N	post-test mean	SD	Post post-test mean	SD
Experimental	67	41	6.2	42.7	7.1
Control	40	33	4.8	33.3	4.9
Mean Difference		8		9.4	
Total	107				

Table 1 indicates that National Diploma students taught calculus concepts using Jigsaw IV cooperative learning strategy demonstrated higher retention ability than those taught using conventional lecture method. Specifically, the experimental group recorded a higher Post post-test mean score of 42.7 and standard deviation (SD) 7.1 compared to the control group with mean score of 33.3 and standard deviation of 4.9, yielding a mean difference of 9.4. This shows that students exposed to Jigsaw IV Cooperative Learning strategy retained calculus concepts better than those taught with the conventional lecture method.

Hypothesis 1

H_{01}: There is no significant difference in the retention ability of National Diploma students taught Calculus using the Jigsaw IV Cooperative Learning Strategy and those taught using the conventional lecture method.

Table 2: ANCOVA Result of Difference in Mean Academic Retention Ability of Students taught Calculus using Jigsaw IV Cooperative Learning Strategy and Conventional Learning Strategy

Source	Type III Sum of Squares	df	Mean Square	F	sig	Partial η^2
Corrected Model	2210.88	2	1105.44	26.38	0.000	0.336
Intercept	102334.71	1	102334.71	2440.21	0.000	0.959
Post-test (Covariate)	398.21	1	398.21	9.52	0.003	0.84
Group	1812.67	1	1812.67	43.21	0.000	0.293
Error	4360.44	104	41.93			
Total	204563.00	107				
Corrected Total	6571.32	106				

Table 2 shows that the experimental group significantly outperformed the control group, indicating that the observed difference in retention was not due to initial achievement differences but rather to the teaching strategy employed.

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Table 3: T-test on students' Retention Abilities of Experimental and Control Groups;

Group	N	Mean	SD	T_{cal}	t_{crit}	Df	Remark
Experimental	67	42.70	7.10	7.45	1.98	105	S
Control	40	33.30	4.90				

S = significant

Table 3 shows that the mean scores of post – posttest of both the experimental and control groups with the mean of 42.70 and 33.30 respectively. The hypothesis two says "there is no significant difference in the retention ability of ND students taught Calculus using the Jigsaw IV Cooperative Learning Strategy and those taught using the conventional lecture method". But from the table above we have t-calculated of 7.45 while the t-critical is 1.98, at α=0.05 this confirm that the observed difference did not occur by chance. Thus, the null hypothesis is rejected since t-cal is greater than t-crit. The independent samples t – test indicates a statistically significant difference in the post post-test score of ND students taught calculus concepts using Jigsaw IV cooperative learning strategy and those taught using the conventional lecture method. Thus, the experimental group had higher retention abilities.

Discussion of the Findings

The paper investigated the effect of Jigsaw IV cooperative learning strategy on retention in calculus among national diploma students in public polytechnic in Kaduna State. One hypothesis was stated and tested based on Jigsaw IV Cooperative learning strategy and Calculus Achievement Test (CAT) was developed and administered to the sampled groups consisting of 107 students. These were selected by sampling; data were collected for which descriptive and inferential statistics were used to describe and analyze the data collected from the sampled population. Analysis of the data collected ware presented in table 1 - 3 in accordance with the stated hypothesis.

The hypothesis one tested significant between the retention ability of ND students taught calculus using Jigsaw IV Cooperative Learning Strategy and those taught using the conventional lecture method. The research question one is answered by testing the corresponding hypothesis which state that "there is no significant difference in the retention ability of ND students taught Calculus using the Jigsaw IV Cooperative Learning Strategy and those taught using the conventional lecture method". The results presented in Tables 1, 2 and 3 clearly indicate a statistically significant difference in favor of the experimental group. The experimental group, which ware taught calculus concepts using the Jigsaw IV strategy, recorded a higher post-posttest mean score (42.7) compared to the control group (33.3), with a mean difference of 9.4. This shows that, there was a positive effect the Jigsaw IV Cooperative Learning Strategy on retention ability on the experimental group. These findings align with the work of Omoroh and Bomboi (2024), who reported that the jigsaw cooperative learning approach has a greater ability to enhance students' retention of mathematics knowledge than the lecture method. Similarly, Eraikhuemen, *et al.,* (2025) reported that Jigsaw Cooperative Instructional Strategy enhanced students' acquisition and retention of mathematics process skills. Chianson, *et al.,* (2011) found that collaborative learning strategies produce better retention in students than conventional methods.

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Conclusion

The paper study the effect of Jigsaw IV cooperative learning strategy on retention in calculus among national diploma students in public polytechnic in Kaduna State. It was shown that better retention ability was recorded on student that were taught Calculus concepts using Jigsaw IV cooperative learning strategy compared to their counterpart that were taught using conventional lecture method.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Lecturers in public polytechnics, especially those teaching Calculus and other core mathematics courses, should adopt the Jigsaw IV Cooperative Learning Strategy as an effective alternative to the conventional lecture method. This strategy will not only improve students' immediate test scores but also enhance their long-term retention of concepts.
2. The National Board for Technical Education (NBTE) should incorporate the Jigsaw IV Cooperative Learning Strategy into the recommended teaching methodologies for mathematics and science-related courses in the national curriculum. Workshops and training manuals should be developed to familiarize lecturers with this approach.

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Comparative Influence of Digital and Practical-Based Instructional Strategies on Academic Achievement among Secondary School Technical Students in Katsina State, Nigeria

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Abstract

This study examined the influence of digital and practical-based instruction on students' academic achievement in Technical and Biology Education among Technical Secondary School students in Katsina State, Nigeria. The study was guided by four objectives and corresponding research questions and hypotheses. A survey research design was adopted for the study. The population comprised 1,666 respondents, from which a sample size of 313 respondents was selected, including 80 female students. Data were collected using a structured questionnaire titled Digital and Practical-Based Instruction and Students' Achievement Questionnaire (DPBI-SAAQ) designed on a five-point Likert scale. The instrument was validated by experts, while its reliability was established using Cronbach's Alpha, yielding a reliability coefficient of 0.742. Data collected were analyzed using Pearson Product Moment Correlation (PPMC), multiple regression analysis, and independent samples t-test at a 0.05 level of significance. The findings revealed that digital instructional methods had a significant positive relationship with students' academic achievement ($r = 0.486$, $p < 0.05$). Practical-based instruction also showed a significant positive effect on students' academic achievement ($r = 0.590$, $p < 0.05$). The combined effect of digital and practical-based instruction significantly predicted students' academic achievement, with practical-based instruction having a stronger predictive influence. The study further revealed that gender significantly influenced students' academic achievement. The study concluded that the integration of digital and practical-based instructional strategies enhances students' academic performance and recommended improved digital infrastructure, adequate practical facilities, and teacher training programmes in technical secondary schools.

Keywords: Digital instruction, practical-based instruction, technical education, biology education

Introduction

The transformation of education in the 21st century has been significantly driven by the integration of digital technologies and the increasing emphasis on experiential, skills-based learning. Within the domains of Technical and Biology Education, these transformations are particularly critical, as they directly influence students' ability to acquire both theoretical knowledge and practical competencies necessary for scientific and technological advancement. Contemporary educational discourse highlights that effective teaching in STEM-related fields requires a blend of digital instructional strategies and hands-on practical experiences to enhance meaningful learning and academic achievement (OECD, 2021; UNESCO, 2023). Digital instruction refers to the use of technology-enhanced teaching tools such as multimedia presentations, virtual simulations, e-learning

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platforms, and interactive software to facilitate learning. The integration of digital tools into classroom instruction has been shown to improve students' engagement, motivation, and conceptual understanding. According to Bond et al. (2020), digital learning environments enable flexible and student-centered approaches that support diverse learning styles. Similarly, Chiu (2021) found that the use of digital technologies significantly enhances students' cognitive engagement and academic performance when properly integrated into teaching practices.

In the context of Biology, digital tools such as virtual laboratories and simulations have been found to improve students' understanding of abstract concepts that are otherwise difficult to visualize in traditional classroom settings (Martín-Gutiérrez et al., 2020). Likewise, in Technical Education, digital technologies facilitate the development of problem-solving and design skills through interactive and application-based learning environments (Adedoyin & Soykan, 2023). However, despite these benefits, the effective implementation of digital instruction in many developing countries, including Nigeria, remains constrained by inadequate infrastructure, limited access to devices, and insufficient teacher training (Yusuf & Bello, 2022). Complementing digital instruction is practical-based instruction, which emphasizes learning through hands-on activities, laboratory experiments, and workshop practices. Practical learning is fundamental in both Biology and Technical Education, as it bridges the gap between theory and real-world application. Research indicates that students who engage in practical activities demonstrate higher retention of knowledge, improved critical thinking skills, and greater interest in learning (Okoye & Nwoye, 2021). Practical-based instruction also supports the development of psychomotor skills, which are essential in technical and vocational education contexts. Recent studies have emphasized that practical learning environments significantly enhance students' academic achievement by promoting active participation and experiential learning (Darling-Hammond et al., 2020). In Biology, laboratory-based instruction has been linked to improved understanding of scientific processes and increased performance in assessments. Similarly, in Technical Education, workshop-based learning enables students to acquire competencies that are directly applicable to industry demands (UNESCO, 2023).

The concept of academic achievement, which represents students' performance in tests, examinations, and overall learning outcomes, remains a key indicator of educational effectiveness. Academic achievement is influenced by multiple factors, including instructional methods, learning environment, student motivation, and access to resources. Studies have shown that innovative teaching approaches, particularly those that integrate digital and practical elements, have a significant positive impact on students' academic performance (Schindler et al., 2021).
Importantly, emerging research suggests that the combined use of digital and practical-based instruction produces synergistic effects on learning outcomes. When students are exposed to both technology-enhanced learning and hands-on experiences, they are more likely to develop deeper understanding, improved problem-solving abilities, and sustained academic interest (Chiu, 2021; OECD, 2021). This integrated approach aligns with constructivist learning theory, which posits that knowledge is actively constructed through interaction and experience. In Katsina State, where technical schools play a crucial role in developing skilled manpower, challenges such as inadequate digital infrastructure, insufficient laboratory and workshop facilities, and disparities in resource distribution continue to affect the quality of education. Consequently, there is a need for empirical investigation into how digital and practical-based instruction influence students' academic achievement in Technical and Biology Education within this context.

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This study is anchored on Constructivist Learning Theory and Experiential Learning Theory, both of which provide a strong conceptual basis for understanding how digital and practical-based instructional strategies influence students' academic achievement in Technical and Biology Education. Constructivist Learning Theory, primarily associated with Jean Piaget and later expanded by Lev Vygotsky, posits that learners actively construct knowledge through interaction with their environment rather than passively receiving information. According to this theory, learning occurs when students engage with content, explore ideas, and build their own understanding based on prior knowledge and experiences. In contemporary education, constructivism strongly supports the use of digital instructional tools, which create interactive and learner-centered environments. Digital platforms such as simulations, multimedia presentations, and virtual laboratories allow students to explore abstract concepts, visualize processes, and engage in self-directed learning. These tools align with constructivist principles by promoting active participation, collaboration, and critical thinking (Schindler et al., 2021). This theory provides a strong foundation for practical-based instruction, which is central to Technical and Biology Education. Practical activities such as laboratory experiments, workshop practices, and hands-on demonstrations enable students to engage directly with learning materials, thereby facilitating deeper understanding and skill acquisition.

In Biology Education, experiential learning occurs when students conduct experiments, observe biological phenomena, and analyze results. Similarly, in Technical Education, students develop competencies through workshop activities, equipment handling, and real-world problem-solving tasks. These experiences align with Kolb's learning cycle by allowing students to apply theoretical knowledge in practical contexts. Empirical evidence suggests that experiential learning significantly enhances students' retention, motivation, and academic performance (Darling-Hammond et al., 2020). In this study, practical-based instruction is expected to positively influence students' academic achievement by providing opportunities for active engagement and skill development. The application of these theories is particularly relevant to Technical and Biology Education, where both conceptual understanding and practical competence are essential. Constructivist theory justifies the use of digital technologies to facilitate interactive learning, while experiential learning theory underscores the importance of hands-on activities in developing skills and knowledge. By integrating these theoretical perspectives, the study provides a robust framework for examining how digital and practical-based instructional strategies influence students' academic achievement. This alignment also supports the study's hypotheses, which seek to determine the individual and combined effects of these instructional approaches. This study, therefore, seeks to examine the impact of digital and practical-based instruction on students' academic achievement, while also considering the influence of demographic variables such as gender and school location. The findings are expected to contribute to the improvement of instructional practices and policy formulation aimed at enhancing educational outcomes in technical and science education.

Statement of the Problem

The rapid advancement of digital technologies and the growing emphasis on skill-based learning have significantly transformed educational practices worldwide. In contemporary education systems, particularly within Science, Technology, Engineering, and Mathematics (STEM) domains, the integration of digital instructional tools alongside practical-based learning has been identified as a critical driver of students' academic success and employability skills (OECD, 2021; UNESCO, 2023). However, despite these global advancements, many developing countries continue to face challenges in effectively integrating these instructional approaches into classroom practices. In Nigeria, technical and science education including Biology plays a vital role in fostering innovation,

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technological development, and national economic growth. Nevertheless, evidence suggests that students' academic achievement in these subject areas remains relatively low, often attributed to inadequate instructional strategies, limited access to digital resources, and insufficient emphasis on hands-on practical learning (Aina, 2020; Yusuf & Bello, 2022). The persistence of traditional lecture-based teaching methods has further constrained students' ability to develop critical thinking, problem-solving skills, and conceptual understanding required in modern education (Adedoyin & Soykan, 2023). In Katsina State, where secondary schools are expected to produce skilled and competent graduates, concerns persist regarding students' academic performance and readiness for the workforce. Factors such as inadequate infrastructure, disparities in school location, and limited exposure to modern teaching methods may further exacerbate these challenges. Despite policy efforts to promote digital education and practical skills acquisition, the extent to which these approaches influence students' academic achievement remains insufficiently explored. Therefore, the problem of this study lies in the lack of empirical evidence on the influence of digital and practical-based instruction on students' academic achievement in Technical Education and Biology in secondary schools of Katsina State. Addressing this gap is essential for informing educational policy, improving instructional practices, and enhancing students' learning outcomes in line with global educational standards.

Objectives of the Study

This study is guided through the following specific objectives:

1. To determine the impact of digital instructional methods on students' academic achievement among Technical Secondary School Students in Katsina State.
2. To examine the effect of practical-based instruction on students' academic achievement among Technical Secondary School Students in Katsina State.
3. To assess the combined effect of digital and practical-based instruction on students' academic achievement among Technical Secondary School Students in Katsina State.

Null Hypotheses

Tested at 0.05 level of significance:

H_{01}: Digital instructional methods have no significant influence on students' academic achievement among Secondary School Students in Katsina State.

H_{02}: Practical-based instruction has no significant influence on students' academic achievement among Secondary School Students in Katsina State.

H_{03}: There is no significant influence of digital and practical-based instruction on students' achievement among Secondary School Students in Katsina State.

Research Methodology

The study adopted a survey research design to investigate the influence of digital instructional methods and practical-based instruction on students' academic achievement. The survey design was considered appropriate because it enabled the researcher to collect data from a large number of respondents regarding their perceptions and experiences without manipulating the study variables. The population of the study comprised 1,666 respondents drawn from the target schools used for the study. From the total population, a sample size of 313 respondents was selected to participate in the study, out of which 80 were female students while the remaining respondents were male students. The sample size was considered adequate to provide reliable information capable of achieving the objectives of the study and testing the formulated hypotheses. Data for the study were collected using a structured questionnaire titled Digital and Practical-Based Instruction and Students' Achievement Questionnaire (DPBI-SAAQ) developed by the researchers. The instrument

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was designed using a five-point Likert scale consisting of Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D), and Strongly Disagree (SD). The questionnaire was divided into four sections namely Sections A, B, C, and D. Section A elicited information on respondents' demographic characteristics, particularly gender, while Section B contained items on digital instructional methods. Section C focused on practical-based instruction, whereas Section D is a proforma used to collect the already students academic achievement. The instrument was subjected to face and content validation by experts to ensure its suitability for the study. The reliability of the instrument was established using Cronbach's Alpha reliability technique, which yielded a reliability coefficient of 0.742, indicating that the instrument possessed acceptable internal consistency and was reliable for data collection. The questionnaires were administered directly to the respondents by the researchers with the assistance of research assistants where necessary. The completed copies of the questionnaire were retrieved immediately after administration to ensure a high response rate and reduce the possibility of data loss. The data collected were analyzed using the Statistical Package for Social Sciences (SPSS) version 27. Pearson Product Moment Correlation (PPMC) was used to test hypotheses one and two in order to determine the relationships between digital instructional methods, practical-based instruction, and students' academic achievement. Multiple regression analysis was employed to test hypothesis three on the influence of digital and practical-based instruction on students' academic achievement, while independent samples t-test was used to test hypothesis four on the influence of gender on students' academic achievement. All hypotheses were tested at a 0.05 level of significance.

Presentation of Results

H_{01}: Digital instructional methods have no significant influence on students' academic achievement among Secondary School Students in Katsina State.

Table 1: Correlation between Digital Instruction and Students' Academic Achievement.

		Digital Instruction	Academic Achievement
Digital Instruction	Pearson Correlation	1	.486**
	Sig. (2-tailed)		.000
	N	313	313
Academic Achievement	Pearson Correlation	.486**	1
	Sig. (2-tailed)	.000	
	N	313	313

**. Correlation is significant at the 0.01 level (2-tailed).

Table 1 examined the relationship between digital instructional methods and students' academic achievement. The Pearson Product Moment Correlation analysis revealed a correlation coefficient of r = 0.486 with a significance value of p = 0000, which is less than the 0.050 level of significance. This indicates that there is a statistically significant positive relationship between digital instruction and students' academic achievement. The positive correlation suggests that the use of digital instructional methods contributes meaningfully to improved academic performance among students. In practical terms, the finding implies that students exposed to digital learning tools, technology supported teaching strategies, and electronic instructional resources are more likely to perform better academically. The moderate strength of the relationship also indicates that digital instruction plays an important role in enhancing learning outcomes, although other factors may also contribute to students' achievement. based on the result, the null hypothesis stating that digital instructional methods have no significant impact on students' academic achievement was rejected. The study

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therefore concludes that digital instructional methods significantly influence students' academic achievement.

H_{02}: Practical-based instruction has no significant influence on students' academic achievement among Secondary School Students in Katsina State.

Table 2: Correlation between Practical-Based Instruction and Students' Academic Achievement

		Practical-Based Instruction	Academic Achievement
Practical-Based Instruction	Pearson Correlation	1	.590**
	Sig. (2-tailed)		.000
	N	313	313
Academic Achievement	Pearson Correlation	.590**	1
	Sig. (2-tailed)	.000	
	N	313	313

Table 2 presents the relationship between practical based instruction and students' academic achievement. The result showed r = 0.590 and a significance value of p = 0.000, which is below the 0.05 alpha level. This demonstrates that a significant positive relationship exists between practical based instruction and students' academic achievement. The correlation coefficient of 0.590 indicates a relatively strong positive association, implying that practical oriented teaching approaches substantially improve students' academic performance. This means that when students engage actively in experiments, demonstrations, hands-on activities, and practical learning experiences, their understanding and practical learning experiences, their understanding and retention of concepts improve significantly, thereby enhancing academic achievement. The finding further suggests that practical based instruction is highly effective in promoting meaningful learning because it enables students to connect theoretical knowledge with real-life applications. Consequently, the null hypothesis which stated that practical based instruction has no significant effect on students' academic achievement was rejected. The study therefore concludes that practical based instruction significantly enhances students' academic achievement.

H_{03}: There is no significant influence on the digital and practical-based instruction on students' achievement among Secondary School Students in Katsina State.

Table 3: Influence of Digital and Practical-Based Instruction on Students' Achievement.

Model	B	Std. Error	Beta	t	Sig.
Constant	1.000	1.636		.611	.542
Digital Instruction	.286	.062	.242	4.635	.000
Practical-Based Instruction	.486	.055	.462	8.844	.000

Table 3 examined the combined effect of digital instruction and practical-based instruction on students' academic achievement. The result revealed that digital instruction had a standardized beta coefficient of β = 0.242 with t = 4.635 and p = 0.000, while practical-based instruction had a standardized beta coefficient of β = 0.462 with t = 8.844 and p = 0.000. The results indicate that both digital instruction and practical based instruction jointly and independently contribute significantly to students' academic achievement compared to digital instruction, as indicated by the higher beta coefficient value. This finding implies that integrating both digital teaching approaches and practical learning experiences creates a more effective learning environment capable of improving students' academic outcomes. The result also highlights the importance of adopting innovative and learner-centered instructional strategies in the teaching-learning process. since the

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significance values for both predictors were less 0.05, the null hypothesis stating that there is no significant combined effect of digital and practical-based instruction on students' achievement was rejected. The study therefore concludes that the combined application of digital and practical based instructional methods significantly predicts students' academic achievement.

Discussion of Findings

The findings of the study revealed that digital instructional methods have a significant positive relationship with students' academic achievement among Technical Secondary School students in Katsina State, with a correlation coefficient of $r = 0.486$ and $p < 0.05$. This finding indicates that the use of digital instructional tools such as multimedia resources, virtual simulations, e-learning platforms, and technology-supported teaching strategies contributes meaningfully to students' academic performance. The result is consistent with the findings of Tsz Kit Chiu who reported that digital learning environments significantly improve students' engagement, motivation, and academic achievement when effectively integrated into classroom instruction (Chiu, 2021). Similarly, the finding agrees with the study of Michael Bond et al. (2020), who found that digital technologies enhance students' cognitive participation and support flexible learner-centered approaches that improve academic outcomes. The finding is also in line with the work of Linda Darling-Hammond et al. (2020), who concluded that technology-enhanced instruction promotes deeper learning, critical thinking, and improved academic performance among learners. However, the finding contradicts the study conducted by John Aina (2020), who reported that inadequate digital infrastructure and limited teacher competence hinder the effectiveness of digital learning in some Nigerian secondary schools. The study further revealed that practical-based instruction has a significant positive effect on students' academic achievement, with a correlation coefficient of $r = 0.590$ and $p < 0.05$. This finding suggests that practical-oriented instructional approaches such as laboratory experiments, demonstrations, workshop activities, and hands-on learning experiences significantly enhance students' understanding and retention of concepts. The finding is similar to the study by Kennedy Okoye and Mary Nwoye (2021), who found that practical learning activities improve students' psychomotor skills, conceptual understanding, and academic performance. The result also supports the findings of David Kolb whose experiential learning principles emphasize learning through active participation and real-life experience (Kolb, 1984). In addition, the finding agrees with Martín-Gutiérrez et al. (2020), who established that practical and simulation-based learning environments improve students' comprehension and achievement in science and technical education. Nevertheless, the finding differs from Yusuf and Bello (2022), who observed that inadequate laboratory facilities and insufficient practical equipment in many Nigerian schools negatively affect the implementation of practical-based instruction. The result of the study also showed that digital and practical-based instructional methods jointly and independently contribute significantly to students' academic achievement. The regression analysis indicated that practical-based instruction had a higher predictive influence ($\beta = 0.462$) than digital instruction ($\beta = 0.242$), although both variables were statistically significant at $p < 0.05$. This finding implies that the integration of digital technologies with practical learning experiences creates a more effective and learner-centered instructional environment capable of improving students' academic outcomes. The finding corroborates the study of Schindler et al. (2021), who reported that blended instructional approaches combining technology and active learning significantly improve students' engagement and achievement. Similarly, OECD (2021) emphasized that modern instructional practices that integrate digital and experiential learning enhance students' problem-solving abilities and academic success. The finding also supports the Constructivist Learning Theory and Experiential Learning Theory underpinning this

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study, which emphasize active participation, interaction, and practical experience in the learning process.

Conclusion

The study concluded that digital instructional methods significantly enhance students' academic achievement among Technical Secondary School students in Katsina State. The integration of digital learning tools such as multimedia resources, virtual simulations, and e-learning platforms improves students' engagement, motivation, conceptual understanding, and academic performance. The study also established that practical-based instruction significantly contributes to improved academic achievement by promoting experiential learning, hands-on activities, and real-life application of knowledge. Practical learning approaches enable students to connect theoretical concepts with practical experiences, thereby enhancing retention, understanding, and problem-solving abilities. The study further concluded that the combined application of digital and practical-based instructional methods provides a more effective instructional environment than the use of either method independently. The integration of both approaches promotes learner-centered instruction, active participation, creativity, and critical thinking, which are essential for meaningful learning and improved academic outcomes in Technical and Biology Education. In addition, the study established that gender significantly influences students' academic achievement, indicating that demographic and socio-cultural factors may affect students' access to learning opportunities and participation in digital and practical learning activities. The findings of the study demonstrate that innovative instructional strategies are essential for improving the quality of teaching Technical Education and Biology in secondary schools. The study therefore emphasizes the need for improved digital infrastructure, adequate practical facilities, teacher capacity development, and supportive educational policies to enhance students' academic achievement and prepare them for contemporary scientific and technological challenges.

Recommendations

1. The Katsina State Ministry of Education should provide adequate digital infrastructure such as computers, internet facilities, multimedia projectors, and e-learning platforms in technical secondary schools to enhance the effective implementation of digital instructional methods.
2. School administrators and the National Board for Technical Education should ensure the provision and maintenance of functional laboratories, workshops, and practical equipment to strengthen practical-based instruction in Technical and Biology Education.
3. The Teachers Registration Council of Nigeria and educational training institutions should organize regular workshops, seminars, and professional development programmes to improve teachers' competence in the use of digital technologies and practical instructional strategies.
4. The Federal Ministry of Education should formulate and implement policies that encourage the integration of blended instructional approaches combining digital and practical-based learning in secondary school curricula.

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Correlation Between Access and Utilization of Digital Tools for Instruction Among Federal Tertiary Institution Lecturers in Kaduna State, Nigeria

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Abstract

The integration of digital technologies has become central to effective teaching and learning in higher education, particularly in Computer Science education. This study assessed the accessibility and utilization of digital tools for Computer Science education among lecturers in federal tertiary institutions in Kaduna State, Nigeria. A cross-sectional descriptive survey design was adopted. The population comprised 202 Computer Science lecturers, and a census sampling technique was employed. Of the 202 questionnaires administered, 192 were valid for analysis. Data were collected using a validated questionnaire with a reliability coefficient of 0.75 (Cronbach's Alpha). Descriptive statistics and inferential statistics, including Pearson Product-Moment Correlation, independent samples t-test, and one-way Analysis of Variance (ANOVA), were used to analyze the data at the 0.05 level of significance. The findings revealed that lecturers utilized digital tools for Computer Science education to a high extent (grand mean = 2.56). A moderate positive and statistically significant relationship was found between accessibility and utilization of digital tools ($r = 0.521$, $r^2 = 0.271$, $p < 0.05$), indicating that accessibility accounted for 27.1% of the variance in lecturers' utilization of digital tools. However, no significant difference was found in accessibility based on gender ($t(190) = 1.327$, $p > 0.05$), and no significant difference was observed in utilization based on years of teaching experience ($F(3,188) = 1.642$, $p > 0.05$). The study concluded that accessibility significantly influences lecturers' utilization of digital tools, although other factors also contribute to technology use, while gender and teaching experience do not significantly affect accessibility or utilization. The study recommends improving ICT infrastructure, ensuring equitable access to digital resources, and providing continuous professional development programmes to strengthen the integration of digital tools in Computer Science education.

Keywords: Digital tools, accessibility, utilization, Computer Science education, lecturers and ICT integration.

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Introduction

The integration of digital technologies into higher education has transformed teaching and learning practices worldwide. As educational institutions increasingly embrace digital transformation, lecturers are expected to utilize technological tools that enhance instructional delivery, learner engagement, collaboration and knowledge acquisition. Digital tools have become essential components of modern pedagogy, enabling educators to create flexible, interactive and learner-centered environments that support the development of twenty-first-century skills (Bond et al., 2024). Consequently, the effective adoption and utilization of digital technologies have become critical indicators of educational quality and institutional readiness in the digital era. Higher education has a wide range of digital tools employed to facilitate teaching and learning activities. These include learning management systems such as Moodle and Google Classroom; communication and collaboration platforms such as Microsoft Teams and Zoom; programming and software development tools such as Visual Studio Code and GitHub; virtual laboratory applications such as Cisco Packet Tracer; artificial intelligence tools such as ChatGPT and Google Gemini; assessment platforms such as Kahoot and Quizizz; and cloud computing services including Microsoft Azure and Amazon Web Services. These technologies support content delivery, online collaboration, virtual experimentation, assessment and communication between lecturers and students, thereby enhancing teaching effectiveness and learning outcomes (Qureshi, 2023; Smith et al., 2024; Ohanu et al., 2024).

Furthermore, the relevance of digital tools is particularly evident in Computer Science education due to the practical and technology-oriented nature of the discipline, which involves the teaching of programming, networking, database management, software engineering, cybersecurity, cloud computing, artificial intelligence and data science, all of which require extensive interaction with digital technologies. Through the use of digital tools, lecturers can demonstrate complex concepts, simulate real-world computing environments, facilitate collaborative problem-solving and provide immediate feedback to learners. Recent advancements in artificial intelligence, cloud computing and collaborative coding platforms have further expanded opportunities for innovative teaching approaches in Computer Science education, thereby improving students' learning experiences and preparing them for the demands of the digital economy (López-Fernández & Vergaz, 2024; Smith et al., 2024). Globally, higher education institutions have increased investments in digital infrastructure and technology-enhanced learning systems to support educational innovation and improve learning outcomes. The COVID-19 pandemic accelerated this trend by compelling institutions to adopt online and blended learning approaches, highlighting the importance of digital readiness among lecturers and students. Studies have shown that lecturers who effectively utilize digital tools are more likely to create engaging learning environments, promote active participation and support personalized learning experiences (Ntim, 2024). As a result, digital competence and technology integration have become essential professional requirements for educators in contemporary higher education. Despite the growing adoption of digital technologies, significant disparities remain in access to and utilization of digital tools, particularly in developing countries. Factors such as inadequate technological infrastructure, unstable internet connectivity, insufficient institutional support, limited funding and inadequate professional development opportunities continue to constrain effective technology integration in higher education (Ohanu et al., 2024; Yakubu et al., 2025). These challenges often result in uneven utilization of digital tools among lecturers and limit the potential benefits of technology-enhanced learning. In recent years in Nigeria, efforts to integrate digital technologies into higher education have intensified, driven by government

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policies, institutional reforms and global trends in educational digitalization (Bond et al., 2024; Ntim, 2024). These initiatives have encouraged the adoption of technology-enhanced teaching and learning practices across tertiary institutions. However, empirical evidence suggests that access to and utilization of digital tools vary significantly across institutions and academic disciplines (Ohanu et al., 2024; Yakubu et al., 2025). While some lecturers have effectively integrated digital platforms such as Microsoft Teams, Moodle, Zoom, Google Classroom and AI-enabled applications into their instructional practices, others continue to face challenges related to inadequate infrastructure, limited digital competencies and restricted access to technological resources (Ajayi, 2024; Uko, 2024). These disparities have important implications for instructional effectiveness, student engagement and the overall quality of higher education delivery in Nigeria.

The issue is particularly important in Computer Science education, where digital technologies are not only instructional tools but also fundamental components of the curriculum. Computer Science lecturers are expected to utilize contemporary digital technologies that facilitate practical learning experiences, enhance students' computational skills and align instructional practices with current industry standards and technological trends (López-Fernández & Vergaz, 2024; Smith et al., 2024). Nevertheless, despite the growing integration of digital technologies in higher education, empirical evidence regarding the accessibility and utilization of digital tools among Computer Science lecturers in Nigerian tertiary institutions remains limited (Ajayi, 2024; Uko, 2024), particularly among federal tertiary institutions in Kaduna State. The State of Kaduna hosts several federal tertiary institutions offering Computer Science programmes and contributes significantly to the development of technological and human capital in Northern Nigeria. Understanding the extent to which Computer Science lecturers have access to and utilize digital teaching tools is essential for improving instructional effectiveness, enhancing students' learning experiences and supporting ongoing digital transformation initiatives in higher education (Bond et al., 2024; Ntim, 2024). Although previous studies have examined issues relating to digital literacy, technology adoption and artificial intelligence utilization among lecturers, limited attention has been given to the broader spectrum of digital tools employed in Computer Science education within federal tertiary institutions in Kaduna State (Ohanu et al., 2024; Yakubu et al., 2025). This gap in the literature underscores the need for empirical investigation into the accessibility and utilization of digital tools among Computer Science lecturers in the study area. Therefore, this study assesses the accessibility and utilization of digital tools for Computer Science education among lecturers in federal tertiary institutions in Kaduna State, Nigeria. The findings provided empirical evidence that will guide policymakers, institutional administrators and educational stakeholders in developing strategies to strengthen digital infrastructure, enhance technology integration and improve the quality of Computer Science education in Nigerian higher education institutions.

Objectives of the Study

This study was conducted to achieve the following objectives:

1. assessed the extent of utilization of digital tools for instruction among lecturers in federal tertiary institutions in Kaduna State, Nigeria.

Research Questions

This study was conducted to answer the following questions:

1. What is the extent of utilization of digital tools for instruction among lecturers in federal tertiary institutions in Kaduna State, Nigeria?

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Research Hypotheses

The following hypotheses were formulated to guide the study:

H_{01}: There is no significant difference in the accessibility of digital tools for Instruction between male and female lecturers.

H_{02}: There is no significant difference in the utilization of digital tools for Instruction among lecturers based on years of teaching experience.

H_{03}: There is no significant relationship between accessibility and utilization of digital tools for Instruction among lecturers in federal tertiary institutions in Kaduna State, Nigeria.

Research Methodology

This study adopted a cross-sectional descriptive survey research design to assess the accessibility and utilization of digital tools for Computer Science education among lecturers in federal tertiary institutions in Kaduna State, Nigeria. The design was considered appropriate because it allows for the collection of data from a defined population at a single point in time in order to describe existing conditions and relationships as they naturally occur (Creswell & Creswell, 2022). The population of the study comprised 202 Computer Science lecturers across the seven (7) federal tertiary institutions in Kaduna State, Nigeria. Due to the relatively manageable size of the population, a census sampling technique was employed, whereby the entire population was used for the study. This approach ensures comprehensive coverage, reduces sampling error and enhances the generalizability of findings, particularly in studies with small or inaccessible populations (Makwana, 2023). A total of 202 questionnaires were administered to the respondents, out of which 192 were correctly completed and returned, yielding a high response rate suitable for analysis. Data for the study were collected using a structured and validated questionnaire designed to measure lecturers' accessibility to digital tools and their level of utilization in Computer Science instruction. This approach was adopted in previous related studies by Boor et al. (2026). The instrument demonstrated acceptable reliability, with a Cronbach's alpha coefficient of 0.75, indicating adequate internal consistency. The data collected were analyzed using descriptive and inferential statistics. Descriptive statistics such as frequency counts, percentages, mean and standard deviation were used to answer the research questions, while inferential statistics, specifically Pearson Product-Moment Correlation, Independent Samples t-test and One-way Analysis of Variance (ANOVA) and other relevant parametric tests where applicable, were used to test the hypotheses at a 0.05 level of significance.

Answering Research Question

Research Question One: What is the extent of utilization of digital tools for Instruction among lecturers in federal tertiary institutions in Kaduna State, Nigeria?

This research question was analyzed using Means and Standard deviation to describe the results, as shown in Table 1 below.

Table 1: Mean Scores on Responses of Extent of Utilization of Digital Tools for Instruction among Lecturers in Federal Tertiary Institutions in Kaduna State

S/N	Item	VHE	HE	LE	VLE	Mean	SD	Decision
1	I frequently use Learning Management Systems (LMS) such as Moodle or Google Classroom for instructional delivery.	62	79	41	10	3.01	0.82	High Extent
2	I use presentation software (PowerPoint, Google Slides) during Computer Science lectures.	95	71	20	6	3.33	0.73	High Extent

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S/N	Item	VHE	HE	LE	VLE	Mean	SD	Decision
3	I utilize video conferencing tools (Microsoft Teams, Zoom, Google Meet) for teaching.	58	76	46	12	2.42	0.86	Low Extent
4	I use online assessment tools for quizzes, tests and examinations.	52	68	55	17	2.36	0.91	Low Extent
5	I employ digital tools for sharing instructional materials with students.	89	74	23	6	3.08	0.75	High Extent
6	I use programming and coding platforms to facilitate practical Computer Science instruction.	71	66	43	12	2.54	0.88	High Extent
7	I utilize collaborative digital tools to support student group work and projects.	49	72	54	17	2.18	0.90	Low Extent
8	I use digital communication tools (email, chat platforms) to interact with students.	87	78	22	5	3.12	0.72	High Extent
9	I integrate online educational resources into my teaching activities.	68	82	34	8	2.79	0.79	High Extent
10	I use digital tools to provide feedback and monitor students' academic progress.	64	76	42	10	1.77	0.83	Very Low Extent
	Grand Total					**2.56**	**0.82**	**High Extent**

Decision Mean = 2.50

The results presented in Table 1 revealed a grand (cumulative) mean of 2.56, which is slightly higher than the decision mean of 2.50. This indicates that, overall, Computer Science lecturers in federal tertiary institutions in Kaduna State utilize digital tools for Computer Science education to a high extent. The associated standard deviation of 0.82 indicates moderate variation in responses, suggesting that lecturers generally hold similar views regarding their utilization of digital tools, with only slight differences among respondents. However, the item-level results show variations in the extent of utilization. While lecturers reported a high extent of using presentation software, learning management systems, digital communication tools, instructional material-sharing platforms, programming tools, and online educational resources, they reported a low extent of utilizing video conferencing tools, online assessment tools, and collaborative digital tools. The use of digital tools for providing feedback and monitoring students' academic progress was reported to a very low extent. Generally, the findings suggest that although digital tools are generally utilized to a great extent, the level of utilization varies across different instructional applications.

Hypothesis Testing

Hypothesis One: There is no significant difference in the accessibility of digital tools for Instruction among lecturers based on gender.

Table 2: Independent Samples t-test Analysis of Difference in Accessibility of Digital Tools for Instruction among Lecturers Based on Gender

Gender	N	Mean	SD	Df	t-value	p-value	Decision
Male	124	3.15	0.79	190	1.327	0.186	Not Significant
Female	68	3.04	0.84				
Total	192			190	1.327	0.186	Retain

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Significant at p < 0.05

The result presented in Table 3 revealed a t-value of 1.327 with 190 degrees of freedom and a corresponding p-value of 0.186, which is greater than the significance level of 0.05. This indicated that there is no statistically significant difference in the accessibility of digital tools for Computer Science education among lecturers based on gender. Therefore, the null hypothesis was retained. The finding implied that male and female lecturers have similar levels of access to digital tools for Computer Science education in federal tertiary institutions in Kaduna State, Nigeria. The slight difference observed in the mean scores of male lecturers (Mean = 3.15, SD = 0.79) and female lecturers (Mean = 3.04, SD = 0.84) was not statistically significant.

Hypothesis Two: There is no significant difference in the utilization of digital tools for Computer Science education among lecturers based on years of teaching experience.

Table 3: One-Way ANOVA Analysis of Difference in the Utilization of Digital Tools for Instruction among Lecturers Based on Years of Teaching Experience

Source of Variation	Sum of Squares	Df	Mean Square	F	p-value	Decision
Between Groups	2.874	3	0.958	1.642	0.181	Not Significant
Within Groups	109.691	188	0.583			
Total	**112.565**	**191**				

p-value 0.181 ***Significant at p < 0.05***

Group Statistics

Years of Teaching Experience	N	Mean	SD
2–9 Years	58	3.12	0.77
10–19 Years	76	3.09	0.81
20–29 Years	45	2.98	0.79
30–40 Years	13	2.87	0.84
Total	**192**	**3.06**	**0.82**

The result presented in Table 4 revealed an F-value of 1.642 with degrees of freedom (3, 188) and a corresponding p-value of 0.181, which is greater than the significance level of 0.05. This indicates that there is no statistically significant difference in the utilization of digital tools for Computer Science education among lecturers based on their years of teaching experience. Therefore, the null hypothesis was retained. The finding implies that lecturers with different levels of teaching experience, ranging from 2 to 40 years, utilize digital tools for Computer Science education at relatively similar levels. Although slight variations were observed in the mean utilization scores across the experience groups, these differences were not statistically significant. Consequently, years of teaching experience did not significantly influence the utilization of digital tools among lecturers in federal tertiary institutions in Kaduna State, Nigeria.

Hypothesis Three: There is no significant relationship between accessibility and utilization of digital tools for Instruction among lecturers in federal tertiary institutions in Kaduna State, Nigeria.

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Table 4: Pearson Product-Moment Correlation Analysis of the Relationship between Accessibility and Utilization of Digital Tools for Instruction among Lecturers in Federal Tertiary Institutions in Kaduna State, Nigeria

Variables	N	Mean	SD	r	r^2	p-value	Decision
Accessibility of Digital Tools	192	3.11	0.81	0.521	0.271	0.000	Significant
Utilization of Digital Tools	192	2.56	0.82				
orrelation Result	192			0.521	0.271	0.000	Reject H_{01}

The results in Table 4 revealed a moderate positive and statistically significant relationship between accessibility and utilization of digital tools for Computer Science education among lecturers in federal tertiary institutions in Kaduna State ($r = 0.521$, $p < 0.05$). This implies that increased accessibility to digital tools is associated with higher levels of utilization for instructional purposes. The coefficient of determination ($r^2 = 0.271$) indicates that approximately 27.1**%** of the variation in lecturers' utilization of digital tools is explained by their level of accessibility, while the remaining 72.9**%** is attributable to other factors not examined in this study. Since the p-value (0.000) is less than the 0.05 level of significance, the null hypothesis was rejected. The study, therefore, concludes that accessibility has a significant positive relationship with the utilization of digital tools for Computer Science education.

Discussion of Findings

Relationship between Accessibility and Utilization of Digital Tools for Instruction among Lecturers

The findings revealed a moderate, statistically significant positive relationship between accessibility and utilization of digital tools for Computer Science education among lecturers in federal tertiary institutions in Kaduna State, Nigeria ($r = 0.521$, $r^2 = 0.271$, $p < .05$). This indicates that lecturers with greater access to digital tools are more likely to utilize them in their teaching activities. The coefficient of determination ($r^2 = 0.271$) shows that accessibility accounted for approximately 27.1**%** of the variance in the utilization of digital tools among lecturers, while the remaining 72.9**%** may be attributed to other factors not examined in this study, such as digital competence, institutional support, training opportunities, and individual motivation. The finding, therefore, suggests that although accessibility is an important determinant of digital tool utilization, it is not the sole factor influencing lecturers' integration of technology into Computer Science education.

This finding is consistent with recent studies that emphasized the importance of accessibility in promoting the effective use of educational technologies. For instance, Adebayo and Olatunji (2022) reported that access to digital resources significantly predicts lecturers' utilization of technology for instructional delivery in higher institutions. Similarly, Mohammed and Ibrahim (2023) found that lecturers with adequate access to digital devices and internet facilities demonstrated higher levels of technology integration in teaching than those with limited access. Likewise, Eze and Okafor (2021) observed that accessibility to digital infrastructure positively influences educators' adoption and utilization of educational technologies. Yusuf and Ahmed (2024) also reported that improved access to technological resources enhances lecturers' willingness and capacity to integrate digital tools into teaching and learning activities.

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The finding is further supported by the Technology Acceptance Model (TAM), which posits that the availability and accessibility of technological resources influence users' adoption and utilization of technology. When lecturers have reliable access to digital tools and supporting infrastructure, they are more likely to perceive such technologies as useful and incorporate them into their instructional practices. However, the finding contradicts the studies of Nwosu and Chukwu (2021) and Bello and Sani (2022), who argued that accessibility alone does not guarantee utilization, emphasizing that digital competence, institutional policies, and motivation also influence technology use. The variation between these findings and the present study may be due to differences in institutional contexts, technological infrastructure, and lecturers' levels of digital literacy. Overall, the result underscores the importance of improving access to digital technologies while simultaneously strengthening other enabling factors to enhance their effective utilization in Computer Science education.

Accessibility of Digital Tools for Instruction among Lecturers Based on Gender

The findings revealed no statistically significant difference in the accessibility of digital tools for Computer Science education among lecturers based on gender, $t(190) = 1.327$, $p > .05$. Although male lecturers recorded a slightly higher mean accessibility score than female lecturers, the difference was not statistically significant. This finding suggests that both male and female lecturers have relatively equal access to digital tools required for Computer Science education in federal tertiary institutions in Kaduna State. The result implies that institutional efforts to provide digital resources appear to benefit lecturers regardless of gender. This finding is consistent with recent studies that reported no significant gender differences in access to educational technologies among academic staff. For instance, Adeyemi and Lawal (2022) found that male and female lecturers had comparable levels of access to digital instructional resources in tertiary institutions. Similarly, Okeke and Eze (2023) reported that gender did not significantly influence lecturers' accessibility to information and communication technologies for teaching purposes. Likewise, Ibrahim and Yusuf (2021) observed that institutional provision of digital infrastructure has reduced gender disparities in access to educational technologies. In the same vein, Bello and Ahmed (2024) found that both male and female lecturers enjoy similar opportunities to access and utilize technological resources in higher education institutions.

The finding supports the Digital Equity Theory, which advocates equal access to technological resources irrespective of demographic characteristics such as gender. The increasing availability of institutional digital resources and the widespread adoption of technology in higher education may have contributed to reducing gender-based disparities in access. However, the finding differs from those of Aina and Ojo (2021) and Garba and Musa (2022), who reported significant gender differences in access to educational technologies, with male lecturers having greater access than their female counterparts. These researchers attributed the disparities to socio-cultural factors, differences in technology exposure and unequal opportunities for technology utilization. The variation between their findings and the present study may be due to differences in geographical location, institutional support and technological development across the study settings. The finding, therefore, suggests that gender is not a determining factor in lecturers' accessibility to digital tools for Computer Science education in the study area.

Utilization of Digital Tools for Instruction among Lecturers Based on Years of Teaching Experience

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The findings revealed no statistically significant difference in the utilization of digital tools for Computer Science education among lecturers based on years of teaching experience, $F(3,188) = 1.642$, $p > .05$. Although slight variations were observed in the mean utilization scores across the different experience groups, the differences were not statistically significant. This finding suggests that lecturers utilize digital tools at similar levels regardless of whether they are early-career, mid-career or highly experienced educators. The result implies that years of teaching experience do not significantly influence lecturers' adoption and utilization of digital tools for instructional purposes. This finding is consistent with recent studies that have reported that teaching experience does not significantly affect technology utilization among lecturers. For instance, Yusuf and Adewale (2022) found that lecturers with varying levels of teaching experience demonstrated similar patterns of digital technology utilization in instructional activities. Similarly, Okafor and Ezeani (2023) reported that years of teaching experience had no significant influence on lecturers' integration of digital tools in higher education. Likewise, Ibrahim and Hassan (2021) observed that both less experienced and highly experienced lecturers utilized educational technologies at comparable levels due to increased institutional emphasis on digital teaching practices. In the same vein, Mohammed and Bello (2024) reported that continuous professional development and institutional technology support reduce differences in technology utilization across experience levels.

The finding is also supported by the Diffusion of Innovation Theory, which posits that adoption of innovations is influenced by perceived usefulness, compatibility and organizational support rather than merely by years of experience. As digital technologies become increasingly integrated into educational systems, lecturers across different experience levels are encouraged to adopt and utilize them for instructional delivery. However, the finding contradicts the studies of Nwankwo and Obi (2021) and Sani and Abdullahi (2022), who reported that younger and less experienced lecturers tend to utilize digital technologies more extensively than their older counterparts. These researchers argued that younger lecturers are generally more comfortable with emerging technologies and more willing to experiment with digital tools. The disparity between their findings and the present study may be attributed to differences in institutional training opportunities, access to technological resources and the digital competencies of lecturers. The finding, therefore, indicates that years of teaching experience do not constitute a significant barrier to the utilization of digital tools for Computer Science education among lecturers in federal tertiary institutions in Kaduna State, Nigeria.

Conclusion

The study concluded that lecturers in federal tertiary institutions in Kaduna State utilize digital tools for Instruction to a great extent. Accessibility significantly enhances digital tool utilization, while gender and years of teaching experience do not significantly influence accessibility or utilization. Therefore, improving access to digital tools is essential for increasing their effective use in Computer Science education.

Recommendations

1. Federal tertiary institutions should improve the availability and accessibility of digital infrastructure to enhance lecturers' utilization of digital tools.
2. Institutions should ensure equitable access to digital resources and technological support for all lecturers, regardless of gender.
3. Regular training and professional development should be provided to strengthen lecturers' effective use of digital tools, irrespective of teaching experience.

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Perceive Effect of Integrating ChatGpt in Learning Sciences Among Secondary School Students in Kaduna North, Kaduna State, Nigeria

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Abstract

This study examined students' perception on challenges associated with using artificial intelligence (Chat GPT) in learning science in senior secondary schools in Kaduna North Local Government Area, Nigeria. The research design was a cross-sectional survey research design. The population of the study consisted of eight co-educational schools having a total number of two thousand nine hundred and forty three (2,943) of SS III students across the eight secondary schools in Kaduna North Local Government Area. From the population of the study 352 students were selected to form the sample size for the study. The instrument used for data collection was a structured Students 'Artificial Intelligence Opinion Questionnaire (SAIOQ). The reliability coefficient of the instrument was 0.81. The study was guided by two research questions and two null hypotheses tested at the 0.05 level of significance. Descriptive statistics of frequencies and percentages were used to answer research questions, Chi-square (χ2) statistics was used to test null hypotheses. The result of the finding showed no significant difference between students' perceptions and the challenges associated with the use of Chat GPT among secondary school students in Kaduna North. Based on these findings, it was therefore recommended that, students should be trained on the responsible use of Chat GPT. Schools should organize orientation programmes, seminars, and workshops to teach students how to use Chat GPT as a supplementary learning tool while avoiding overdependence on AI-generated responses.

Keywords: Perception, Chat GPT, Artificial Intelligence, Challenges, Science, Learning

Introduction

Chat GPT is a generative artificial intelligence (AI) tool developed by Open AI that uses advanced language processing technology to understand users' questions or instructions and generate human-like text responses (Chukwuere, 2024). Chat GPT can explain concepts, answer questions, summarize information, generate examples, assist with problem-solving, and support learning through interactive dialogue. One of the most prominent developments in education, has been the emergence of generative artificial intelligence (Gen AI) applications such as Chat GPT, which can generate human-like responses to questions, explain concepts and engage learners in interactive conversations. The usage of Chat GPT has expanded rapidly across educational settings ever since Chat GPT was released in the year (2022), creating both opportunities and concerns for teachers and

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students. Research such as Chukwuere (2024) and Oduma, Arisabor, Anthony and Michael (2025) indicates that Chat GPT supports learning through immediate feedback, personalized explanations, accessibility to information, and assistance with complex academic tasks. However, the educational use of Chat GPT could presents challenges relating to accuracy, academic integrity, overdependence, privacy, and the development of students' independent and critical thinking skills (UNESCO, 2026; Nwoye & Okafor, 2026). In education, Chat GPT can function as a virtual learning assistant by providing students with immediate explanations, feedback, study materials, and assistance with academic tasks as reported by Adeyemo and Balogun (2024). The potential usefulness of Chat GPT in learning science must therefore be considered alongside the challenges associated with its use. One of the challenges is the reliability of information generated by AI. Chat GPT does not necessarily distinguish between scientifically accurate information and plausible but incorrect information. Consequently, students who accept AI-generated responses without verification may acquire misconceptions, particularly in science subjects where accuracy and evidence are fundamental. Therefore, this study examined students' perception on challenges associated with using artificial intelligence (Chat GPT) in learning science in senior secondary schools in Kaduna North Local Government Area, Nigeria.

Statement of the Problem

The rapid development of Artificial Intelligence (AI) has introduced new possibilities for teaching and learning across educational systems. One of the most prominent generative Artificial Intelligence applications is Chat GPT, which can explain concepts, provide examples and support students in completing learning activities. In science, Chat GPT may provide students with additional opportunities to clarify difficult concepts in subjects such as Biology, Chemistry, and Physics and to obtain immediate explanations outside the conventional classroom setting. However, the increasing use of Chat GPT in education has also generated concerns regarding the reliability of AI-generated information, academic integrity and the possible effects of AI on critical thinking and independent learning as reported by Akinyemi, Adeyemo and Ojo (2023). The use of Chat GPT in science presents particular challenges, because science learning depends sorely on accuracy of information, problem-solving, experimentation, and ability of learners to evaluate evidence. Chat GPT may produce information that is inaccurate, incomplete or presented without adequate sources. UNESCO (2026) notes that generative AI can create educational opportunities but also raises concerns about misinformation, age appropriateness and the need for appropriate pedagogical and ethical safeguards. Consequently, students who accept AI-generated responses without critically evaluating them may acquire misconceptions or inaccurate scientific knowledge. It is against this background that the present study seeks to investigate students' perception of the challenges associated with using Artificial Intelligence (Chat GPT) in learning science in senior secondary schools in Kaduna North Local Government Area, Nigeria. The study is expected to provide evidence to Kaduna State Ministry of Education that would contribute to the development of appropriate school-level AI-use guidelines for the responsible integration of Chat GPT into science education.

Objectives of the Study

The objectives of this study are to:

1. identify students' perceptions on the challenges associated with the use of Chat GPT in science among senior secondary students in Kaduna North LGA.
2. examine students' perceptions on ways for the effective integration of AI tools into secondary school education in Kaduna North LGA.

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Research Questions

1. What are students' perceptions of the challenges associated with using Chat GPT for learning Science in senior secondary schools in Kaduna North LGA?
2. What are students' perceptions of the measures to enhance the responsible use of AI tools in science in Kaduna North LGA?

Null Hypotheses

1. there is no significant difference between the perceived challenges associated with using Chat GPT for learning Science among senior secondary school students in Kaduna North LGA.
2. there is no significant difference in students' perceptions of the measures for enhancing the responsible use of AI tools in Science in senior secondary schools in Kaduna North LGA.

Research Methodology

This study adopted a cross-sectional survey research design which involves collecting data from a sample of respondents at one point in time to examine the current status of a phenomenon. The design was considered appropriate for this study because it enabled the researcher to gather information on students' perception on the challenges associated with the use of Chat GPT and measures for enhancing the responsible use of AI tools in Science in senior secondary schools in Kaduna North LGA and supported the use of the Students' Artificial Intelligence Opinion Questionnaire (SAIOQ). The study was conducted in Kaduna North Local Government Area, located in the northwestern region of Nigeria and serves as an important urban and administrative center within the state. The Local Government Area is part of Kaduna metropolis and is known for its educational institutions, commercial activities, and diverse population. The population of this study consisted of all SS 3 science students in eight (8) co-educational public secondary schools within Kaduna North LGA, Nigeria. The total number of the SS 3 students from the eight co-educational public schools is two thousand nine hundred and forty three (2,943) students out of which 1,477 were males while 1,466 were females. The sample for this study consisted of three hundred and fifty two (352) SS 3 Science students selected from public senior secondary schools in Kaduna North Local Government Area. The target respondents included students offering science related subjects such as Biology, Chemistry, Physics, and Mathematics at secondary school level. The study adopted a multistage sampling technique, involving purposive sampling and simple random sampling methods. Purposive sampling was first used to select co-educational secondary schools with science students and access to digital learning tools or internet facilities in Kaduna North. Simple random sampling was also used to select the students who participated in the study. This was done by balloting. This was to give every science student an equal chance of being selected, thereby reducing bias and ensuring fairness in the selection process. The sample size for this study was determined using the Taro Yamane (1967) formula for finite population which yielded a sample size of 352. The research instrument developed by the researcher for the purpose of data collection was a structured Students' Artificial Intelligence Opinion Questionnaire (SAIOQ). The SAIOQ contained 30 - items and had two sections; A and B. Section A was on socio-demographic data of the students while section B comprised of questions on students' perception on the challenges associated with the use of Chat GPT and measures for enhancing the responsible use of AI tools in Science in senior secondary schools in Kaduna North.

a) Validation of Students' Artificial Intelligence Opinion Questionnaire (SAIOQ)

The Students' Artificial Intelligence Opinion Questionnaire (SAIOQ) was given to experts from the Department of Science Education, Kaduna State University, with a minimum qualification of Ph.D.

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and also to experts from ICT Department of Kaduna State University. The experts critically checked the content of the instrument to ascertain the appropriateness of the items; whether the test items conform to the subject matter to be tested.

Reliability of Students' Artificial Intelligence Opinion Questionnaire (SAIOQ)

The reliability of the Students' Artificial Intelligence Opinion Questionnaire (SAIOQ) was determined by adopting the Split half reliability method for measurement of the reliability coefficient and internal consistency index of items within the instrument. The reliability coefficient was estimated using the Cronbach Alpha. From the result obtained, the reliability coefficient of the instrument was 0.82.

Ethical Consideration

Ethical approval was sought from the relevant authorities such as; Kaduna State Ministry of Education, science teachers and school administrators to obtain permission from the selected senior secondary schools before data collection begun. Participation in the study was voluntary.

Data Collection and Analysis

The questionnaires were administered to science students in Kaduna North Local Government Area to assess their opinion on the challenges associated with using artificial intelligence (Chat GPT) in learning science in senior secondary schools in Kaduna North. Four possible responses were given by the students which included Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD) by ticking the correct option. To answer the Research Questions, frequencies and percentages were used. To test the Null Hypotheses, Chi-square statistics was used.

Presentation of Results

Research Question 1: What are students' perceptions of the challenges associated with using Chat GPT for learning Science in senior secondary schools in Kaduna North?

To answer research question 1, frequencies and percentages were used. The summary is presented in Table 1.

Table 1: Frequencies and Percentages on Students' Perception on the Challenges associated with the use of Chat GPT

Responses	Frequency	Percentage (%)
Distraction and Misuse	151	42.9
Encourages Overdependence on Technology	33	9.4
Promotes Academic Dishonesty	29	8.2
Reduces Critical Thinking Skills	20	5.7
May Provide Incorrect Information	17	4.8
Weakening of Writing and Research Skills	21	6
Digital Divide and Unequal Access	25	7.1
Limited Understanding of Subject Matter	15	4.3
Privacy and Security Concerns	24	6.8
Reduces Interaction with Teachers and Peers	17	4.8
Total	**352**	**100**

Table 1 showed the rate of responses on students' perception on the challenges associated with the use of Chat GPT among secondary school students in Kaduna North. Results show that, a total of 151(42.9%) students reported that, the use of Chat GPT among secondary school students

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encourages distraction and misuse, while 33(9.4%) reported that, the use of Chat GPT encourages overdependence on technology, 29 respondents representing 8.2% said the use of Chat GPT promotes academic dishonesty while 20 respondents (5.7%) said the use of Chat GPT reduces critical thinking skills. 17(4.8%) said it may provide incorrect information as against 21(6.0%) said it weakening writing and research skills, 25(7.1%) said it creates digital divide and unequal accesses as against 15 representing 4.3% said it has limited understanding of subject matter while 24 representing 6.8% said it has privacy and security concerns and the rest 17(4.8%) said it reduces interaction with teachers and peers. In summary, the main challenges that are associated with the use of Chat GPT among secondary school students in Kaduna North includes distraction and misuse, as well as promotes academic dishonesty. However, the statistical validity of these responses is left for the test of the related hypothesis of the study.

Null Hypothesis One: There is no significant difference between the perceived challenges associated with using Chat GPT for learning Science among senior secondary school students in Kaduna North. To test Null Hypothesis one, Chi-square statistic ($\chi 2$) was used on responses of respondent to the challenges associated with the use of Chat GPT among secondary school students in Kaduna North. The summary of the analysis is presented in Table 2.

Table 2: Chi-square Statistics ($\chi 2$) on Students' Responses on Perceived Challenges Associated with the use of Chat GPT among Secondary School Students in Kaduna

Variable	Frequency Y	Frequency N	Total responses	Df	X^2computed	X^2critical	p-value	Remarks
Challenges using Chat GPT	216	136	352	1	12.9	**16.9**	0.09	NS
	111.0	241.0						

P-value > 0.05. $\chi 2$ computed < $\chi 2$ critical at df 1

The outcome of the chi-square statistics in Table 2 revealed no significant difference between students' perceptions and the challenges associated with the use of Chat GPT among secondary school students in Kaduna North. Reasons being that the calculated p-value of 0.09 is greater than the 0.05 alpha level of significance and its computed chi square ($\chi 2$) value of 12.9 is lower than the 16.9 critical chi-square ($\chi 2$) value at df 1. The maximum frequencies of the observed values were 216 and 136 for total positive and negative responses respectively while their expected values were 111.0 and 241.0 respectively. Therefore, the null hypotheses which state that "There is no significant difference between the perceived challenges associated with using Chat GPT for learning Science among senior secondary school students in Kaduna North." is hereby accepted and retained

Research Question Two: What are students' perceptions of the measures to enhance the responsible use of AI tools in science in Kaduna North?

To answer research question 2, frequencies and percentages were used. The summary is presented in Table 3.

Table 3: Frequencies and Percentages on Students' Perceptions on the Measures to Enhance the Responsible Use of AI tools in Science in Kaduna North?

Responses	Frequency	Percent
Provide Digital Literacy Education	9	2.6
Use Chat GPT as a Supplementary Tool	21	6

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Train Teachers on AI Integration	20	5.7
Encourage Fact-Checking	24	6.8
Develop Clear School Policies	20	5.7
Improve Access to Technology	36	10.2
Monitor and Guide Student Usage	194	55.1
Foster Collaborative Learning	28	8
Total	**352**	**100**

Table 3 showed students' perceptions on measures that can enhance the responsible use of AI tools in science in Kaduna North. A total of 9 respondents (2.6%) reported that, the best measure to enhance the responsible use of AI tools in science is to provide digital literacy education, while 21 (6.0%) suggested, Chat GPT should be used as a supplementary tool only, 20 (5.7%) said teachers should be trained on AI integration. 24 (6.8%) respondents suggested fact checking should be encouraged, while 20 (5.7%) said clear school policies should be developed, also, 36 (10.2%) respondents suggested improvement of access to technology. Similarly, 194 (55.1%) suggested monitoring and guiding students' usage and the rest 28(8.0%) suggested that there should be foster collaboration learning. In summary, the main measures that was suggested to enhance the responsible use of AI tools in science in Kaduna North, is to monitor and guide student usage. However, the statistical validity of these responses is left for the test of the related hypothesis of the study.

Null Hypothesis Two: There is no significant difference in students' perceptions of the measures for enhancing the responsible use of AI tools in Science in senior secondary schools in Kaduna North.

To test Null Hypothesis two, Chi-square statistic ($\chi 2$) was used on students' perceptions of the measures for enhancing the responsible use of AI tools in Science in senior secondary schools in Kaduna North. The summary of the analysis is presented in Table 4.

Table 4: Chi square ($\chi 2$) Statistics on Students' Perceptions of the Measures for enhancing the Responsible use of AI Tools in Science in Kaduna North

Variable	Frequency Y	Frequency N	Total responses	Df	χ^2computed	χ^2critical	p-value	Remarks
Measures to enhance	217 112.6	135 239.3	352	1	13.18	**14.07**	0.44	NS

P-value < 0.05. χ2 computed > χ2 critical at df 1

Table 4 revealed no significant difference between students' perceptions and the measures for enhancing the responsible use of AI tools in science in senior secondary schools in Kaduna North. Reasons being that the p-value of 0.44 is greater than the 0.05 alpha level of significance and its computed chi- square ($\chi 2$) value of 13.18 is lower than the 14.07 critical chi-square ($\chi 2$) value at df 1. The maximum frequencies of the observed values were 217 and 135 for total positive and negative responses respectively while their expected counts were 112.6 and 239.3 respectively. Therefore the null hypotheses which states that, there is no significant difference in students' perceptions of the measures for enhancing the responsible use of AI tools in Science in senior secondary schools in Kaduna North, is hereby accepted and retained

Discussion of Findings

The study examined students' perception on challenges associated with using artificial intelligence (Chat GPT) in learning science in senior secondary schools in Kaduna North Local Government Area, Nigeria. The findings of the study revealed that there was no significant difference between students'

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perceptions and the challenges associated with the use of Chat GPT among secondary school students in Kaduna North. This finding suggests that students' perceptions of Chat GPT are not significantly influenced by the challenges they encounter when using the technology for academic purposes. In other words, although students may recognize certain challenges associated with the use of Chat GPT, such challenges do not appear to substantially alter their overall perceptions of the technology. The absence of a significant difference may indicate that students have developed relatively similar views about both the usefulness and limitations of Chat GPT. Some students may perceive Chat GPT as a valuable educational tool because of its accessibility and ability to provide immediate responses, while also acknowledging challenges such as inaccurate information, overdependence on artificial intelligence, limited critical thinking, and difficulties in determining the reliability of generated responses. These challenges may therefore contribute to shaping students' overall perceptions of Chat GPT. This finding is important because it indicates that the introduction of Chat GPT into secondary school education should be accompanied by appropriate guidance and digital literacy education. Students need to understand that Chat GPT should serve as a supportive learning tool rather than a substitute for independent thinking, teachers, textbooks, and other reliable academic resources. Teachers should also guide students on how to verify information generated by artificial intelligence and use the technology responsibly. The finding further suggests that schools in Kaduna North may need to develop appropriate policies and instructional strategies for the responsible use of generative artificial intelligence. Such measures could help students maximize the educational benefits of Chat GPT while minimizing challenges associated with misuse, dependency, misinformation, and academic dishonesty. Therefore, the absence of a significant difference should not be interpreted as evidence that Chat GPT has no challenges; rather, it suggests that students' perceptions and the challenges they encounter are closely related and do not differ significantly within the context of the study.

Overall, the finding implies that students' experiences with Chat GPT are shaped by both its perceived educational usefulness and the difficulties associated with its use. Consequently, effective supervision, teacher guidance, and digital literacy training are essential for ensuring that Chat GPT contributes positively to teaching and learning among secondary school students in Kaduna North. The finding of the present study is consistent with the findings of Musa, Adamu, and Nuru (2025), who investigated the awareness and utilization of Artificial Intelligence among secondary school Biology students in Lere, Kaduna State and found No significant difference between the awareness and utilization of Artificial Intelligence among secondary school Biology students in Lere, Kaduna State. Similarly, the finding agrees with Egara, Mosimege and Mosia, (2025), who investigated secondary school students' perceptions of their usage of artificial intelligence-based Chat GPT in mathematics learning and reported that students generally perceived Chat GPT positively, particularly because it enhanced their understanding of complex mathematical concepts and supported problem-solving. However, students also expressed concerns about inaccuracies, consistency, overreliance, and limitations in developing independent problem-solving skills. The coexistence of positive perceptions and identified challenges in their study provides support for the present finding that there was no significant difference between students' perceptions and the challenges associated with Chat GPT use. This suggests that students may not necessarily view the challenges associated with Chat GPT as reasons to reject the technology. Rather, they may regard the challenges as limitations that can be managed through appropriate instruction and guidance.
The findings of the study also revealed no significant difference between students' perceptions and the measures for enhancing the responsible use of AI tools in science in senior secondary schools in

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Kaduna North. This finding implies that students' perceptions of AI tools are not significantly different from their views regarding the measures that could promote responsible use of such technologies. The result may suggest that students recognize both the educational benefits of AI and the need for appropriate measures, such as teacher guidance, AI literacy, verification of AI-generated information, respect for academic integrity, and responsible use of AI for learning. The finding is consistent with the study of Akintokun and Bolarinwa (2025), which examined the perceived impact of AI as a science education tool for enhancing students' academic experiences. The researchers reported a favourable perception of AI integration in science education, although several obstacles to effective use were identified. They recommended adequate resources, teacher support, and the incorporation of AI technologies into teaching and learning. This finding agrees with the present study because positive perceptions of AI were accompanied by recognition of the need for appropriate support and measures to ensure effective use. Similarly, the present finding agrees with Adeyemo and Balogun (2024) who examined virtual reality as an AI-driven tool for improving science education in Nigerian secondary schools and found no significant difference between students' perceptions and the measures for enhancing the responsible use of AI tools in science education in senior secondary schools

Conclusion

From the findings of this study, the following conclusions were made:

1. No significant difference between students' perceptions and the challenges associated with the use of Chat GPT among secondary school students in Kaduna North.
2. No significant difference between students' perceptions and the measures for enhancing the responsible use of AI tools in science in senior secondary schools in Kaduna North.

Recommendations

On the basis of the findings from this study, the following recommendations are made:

1. Students should be trained for the responsible use of Chat GPT**.** Schools should organize orientation programmes, seminars, and workshops to teach students how to use Chat GPT as a supplementary learning tool while avoiding overdependence on AI-generated responses.
2. Teachers should provide adequate supervision**.** Science teachers should monitor and guide students' use of AI tools to ensure that such technologies complement classroom teaching rather than replace teachers, textbooks, practical activities, and students' independent thinking.
3. Students should be encouraged to verify information generated by Chat GPT**.** Since AI tools can sometimes provide inaccurate, incomplete, or misleading information, students should be taught to cross-check Chat GPT responses with approved textbooks, teachers, scientific journals, and other reliable sources.

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Awareness, Adoption and Perceived Impact of Artificial Intelligence Utilisation among Professional Diploma Students of Ahmadu Bello University, Zaria, Kaduna State

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Abstract

This study examined artificial intelligence (AI) utilisation among Professional Diploma in Education students at the Institute of Education, Ahmadu Bello University, Zaria, with emphasis on (i) awareness and adoption of AI-related tools and (ii) students' perceived academic benefits of AI use. A descriptive cross-sectional survey design was employed. Forty-two usable responses were obtained from an estimated population of 60 students through simple random sampling. Data were collected using a structured 25-item questionnaire and analysed with frequencies, percentages, means, and standard deviations. Respondents reported high awareness of AI tools (M = 4.38), but only moderate active use (M = 3.23) and limited formal training (M = 2.82). Perceived academic benefits were highest for research efficiency (M = 4.09), time management (M = 4.00), and engagement with course materials (M = 4.00), whereas critical-thinking development received the lowest mean among the six dimensions (M = 3.55). In addition, 78.6% of respondents reported that their academic performance had improved since adopting AI tools. Because these outcomes are self-reported and the study is cross-sectional, the findings should be interpreted as perceived academic benefits rather than causal evidence that AI improves academic performance. The study highlights the need for structured AI-literacy training, clearer institutional guidance, and pedagogical approaches that encourage critical and ethical use of AI in professional education.

Keywords: Artificial Intelligence; AI Awareness; AI Adoption; Professional Diploma in Education

Introduction

The rapid integration of Artificial Intelligence (AI) into educational systems has altered how knowledge is accessed, processed, and applied across levels of learning. AI-supported applications now include intelligent tutoring systems, automated feedback, adaptive learning platforms, natural-language tools, and research assistants. These technologies are increasingly positioned as important components of contemporary educational practice because they can support personalised learning, improve access to academic resources, and reduce some routine academic workloads (Wang et al., 2024; Bali et al., 2024). In Nigeria, interest in AI for education has also increased as institutions seek technology-supported responses to large class sizes, resource limitations, and unequal learning opportunities (Abubakar et al., 2024; Yakubu, 2024). Professional Diploma in Education (PDE)

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students occupy a distinctive position within this development. Many are adult or professionally engaged learners who combine academic responsibilities with employment and personal commitments, creating a strong demand for flexible and efficient learning support (Eteng-Uket & Effiom, 2024). At the Institute of Education, Ahmadu Bello University, Zaria, understanding how PDE students become aware of AI tools, adopt them, and perceive their academic value can provide evidence for institutional training and support. Although the literature on AI in higher education is expanding, empirical evidence focused specifically on professional diploma students in Nigerian university contexts remains limited. Existing studies also frequently discuss awareness and utilisation together even though familiarity with a technology does not necessarily imply sustained or effective academic use. This study therefore focuses on two dimensions: awareness and adoption of AI-related tools, and students' perceptions of the academic benefits associated with their use.

Research Objectives

The study was guided by the following objectives:

1. To assess the level of awareness and adoption of AI-related tools among Professional Diploma in Education students at the Institute of Education, Ahmadu Bello University, Zaria.
2. To examine students' perceived academic benefits associated with the use of AI tools.

Research Questions

1. What is the level of awareness and adoption of AI-related tools among the students?
2. How do students perceive the influence of AI-tool use on selected academic outcomes?

AI in Education: Conceptual Overview

Artificial Intelligence in education encompasses technologies such as intelligent tutoring systems, natural-language processing tools, automated assessment systems, adaptive learning environments, and AI-assisted research applications (Ayeni et al., 2024). A common feature of these systems is their capacity to provide responsive support and reduce the cognitive or logistical burden associated with some academic tasks. Jaiswal and Arun (2021) argue that AI can contribute to the transformation of educational systems by enabling more adaptive and personalised learning experiences. For professional and postgraduate learners, generative AI and other digital academic-support tools may also assist with literature searching, drafting, revision, and organisation of scholarly work. However, the educational value of these tools depends on how they are used and the extent to which users critically evaluate their outputs.

Awareness and Adoption of AI Tools

Awareness and adoption represent related but distinct stages of technology use. Awareness refers to familiarity with the existence and functions of a technology, whereas adoption involves its actual and continuing integration into practice. Diffusion of Innovation theory provides a useful perspective for understanding why awareness may spread more rapidly than sustained use, particularly where institutional support, perceived usefulness, compatibility, and access differ across learners (Phillips, 2025). Studies in Nigerian tertiary institutions similarly report increasing awareness of AI alongside constraints associated with digital infrastructure, training, and academic-integrity concerns (Abubakar et al., 2024; Ibrahim et al., 2024). Evidence from South African higher education also suggests that institutional conditions shape how students and educators engage with AI tools (Khoalenyane & Ajani, 2024).

AI Use and Academic Outcomes

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Research on AI in higher education commonly reports potential benefits for research support, writing, tutoring, feedback, and learning efficiency, while also identifying risks related to over-reliance, academic integrity, and reduced independent engagement. Systematic and review studies indicate that generative AI can support learning when it is integrated purposefully, but outcomes depend on pedagogical design and the manner in which students interact with AI-generated content (Wang et al., 2024; Zhang et al., 2024). Concerns are especially relevant for critical thinking: AI may act as a scaffold for inquiry when learners interrogate and refine its outputs, but passive reliance may reduce opportunities for independent reasoning (Kalniņa et al., 2024; Klimova & Pikhart, 2025).

Theoretical Framework

The study is interpreted primarily through Diffusion of Innovation theory and the Technological Pedagogical Content Knowledge (TPACK) perspective. Diffusion of Innovation provides a basis for examining differences between awareness and sustained adoption, whereas TPACK emphasises that effective educational use of technology depends on the interaction of technological competence, pedagogy, and subject knowledge (Hanifah et al., 2024; Phillips, 2025). Together, these perspectives support the view that exposure to AI alone is insufficient; learners also require structured guidance on when, why, and how AI should be used within academic practice.

Research Methodology

Research Design and Population

The study adopted a descriptive cross-sectional survey design to characterise patterns of AI awareness, adoption, and perceived academic benefits within a defined student population. The target population comprised approximately 60 Professional Diploma in Education students enrolled at the Institute of Education, Ahmadu Bello University, Zaria, across the 2022/2023, 2023/2024, and 2024/2025 academic sessions.

Sample and Sampling Technique

Forty-two usable questionnaires were analysed, representing approximately 70% of the estimated target population. Respondents were selected using simple random sampling. The original manuscript referred to a Yamane-based minimum sample size, but the precision parameter used in that calculation was not documented in the supplied study record; the present revision therefore reports the achieved sample without reproducing an incomplete sample-size calculation.

Instrument and Measurement

Data were collected using a structured 25-item questionnaire organised into five sections: demographic information; AI awareness and adoption; perceived academic benefits; utilisation challenges; and open-ended suggestions for improvement. Items measuring awareness and perceived academic benefits used a five-point Likert response format ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Content and face validity were established through expert review by the project supervisor.

Validity, Reliability and Ethical Reporting

The supplied manuscript documents face and content validity but does not report an internal-consistency coefficient for the Likert scales. It also does not provide an institutional ethics approval or exemption reference, informed-consent procedure, or confidentiality statement. These details have not been invented in this revision and should be added from the original research records before journal submission. Where item-level response counts differ, the valid N is reported directly in the results.

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Data Analysis

Data were analysed using descriptive statistics: frequency counts, percentages, means, and standard deviations. For interpretation of five-point Likert means, scores from 1.00 to 2.49 were classified as low, 2.50 to 3.49 as moderate, and 3.50 to 5.00 as high. The analysis is descriptive; consequently, the findings are interpreted as reported perceptions and patterns rather than causal effects.

Presentation of Results

Objective 1: Awareness and Adoption of AI-Related Tools

The first objective examined the level of awareness and adoption of AI-related tools. Results are presented in terms of the categories of tools reported and respondents' ratings of awareness, use, institutional exposure, understanding, and training.

Reported AI Tool Categories

Table 1: Reported AI Tool Categories

AI Tool Category	Representative Tools	Reported Users
Content Generators	ChatGPT, Gemini, Claude, DeepSeek	10
Proofreading and Paraphrasing Tools	Grammarly, QuillBot	6
Reference Managers	Zotero, Mendeley	4
Research Assistants	Consensus, Elicit	3
General-Purpose AI Tools	ChatGPT, Gemini, Claude, DeepSeek	3
Other Tools	BestAI	1

Note. Frequencies are reproduced from the source data. The percentages in the original manuscript were not retained because they do not correspond to the overall sample of 42 respondents and the valid denominator for this item was not documented. The category labels also overlap for some tools; therefore, the counts should be interpreted as coded responses rather than mutually exclusive adoption rates. Content-generation tools received the highest reported count (10), followed by proofreading and paraphrasing tools (6), reference managers (4), and research assistants (3). The pattern suggests that respondents more frequently reported tools that provide immediate support for drafting and text refinement than tools oriented towards literature discovery or reference organisation. Because the valid denominator and category exclusivity are not documented for this item, percentage-based comparisons are not made.

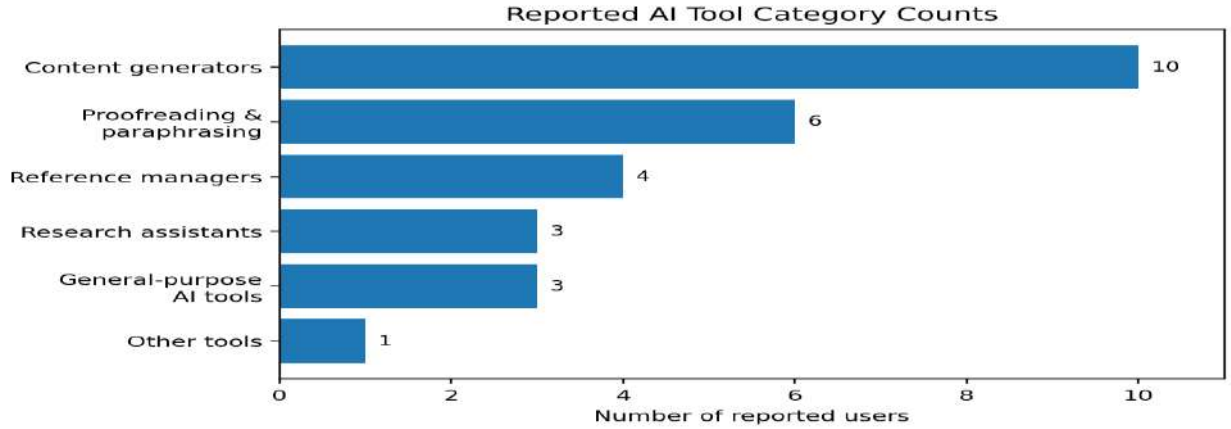


Figure 1: Reported AI Tool Category Counts

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4.1.2 Self-Rated Awareness, Use, Exposure, Understanding, and Training

Table 2: Descriptive Statistics for AI Awareness and Adoption Items

S/N	Item Statement	Valid N	Mean	SD	Interpretation
1	I am aware of AI tools used in education.	39	4.38	1.37	High
2	I actively use AI tools in my academic activities.	39	3.23	1.66	Moderate
3	The university has exposed me to AI tools in learning.	33	3.09	1.49	Moderate
4	I understand how AI tools work in supporting academic tasks.	33	3.64	1.50	High
5	I have attended training or workshops related to AI in education.	33	2.82	1.75	Moderate

Note. Valid response counts vary across items (N = 33–39). The supplied manuscript does not document the reason for the item-level differences. Interpretation scale: 1.00–2.49 = Low; 2.50–3.49 = Moderate; 3.50–5.00 = High. Awareness of AI tools recorded the highest mean (M = 4.38, SD = 1.37), indicating a high level of familiarity among respondents who answered the item. Active academic use was moderate (M = 3.23, SD = 1.66), while perceived university exposure was also moderate (M = 3.09, SD = 1.49). Respondents reported a high level of understanding of how AI tools support academic tasks (M = 3.64, SD = 1.50). Participation in AI-related training or workshops recorded the lowest mean (M = 2.82, SD = 1.75), which falls within the study's moderate range rather than the low range. Overall, the pattern indicates stronger awareness than active use or formal training.

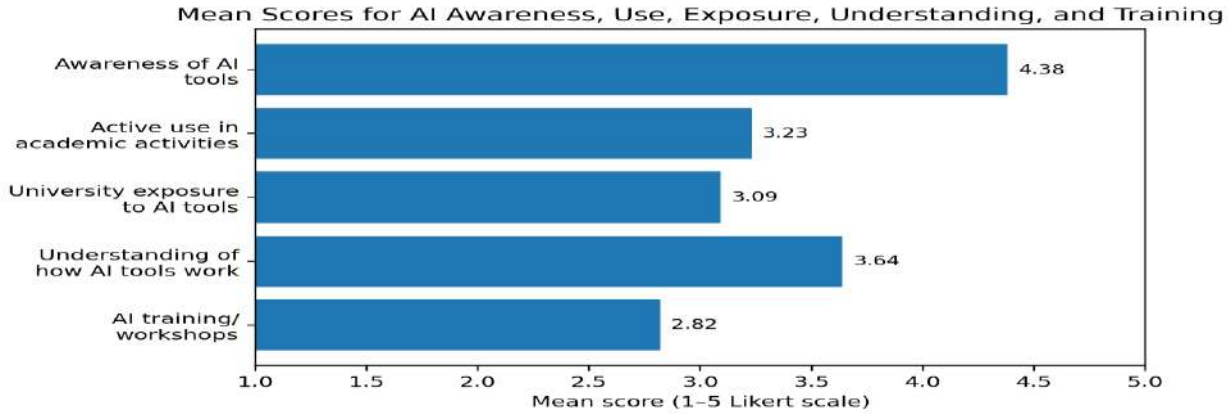


Figure 2: Mean Scores for AI Awareness, Use, Exposure, Understanding, and Training

Objective 2: Perceived Academic Benefits of AI Use

The second objective examined respondents' perceptions of how AI-tool use relates to selected academic outcomes. The results represent perceived benefits and should not be interpreted as objective or causal measures of academic performance.

Perceived Benefits across Academic Dimensions

Table 3: Mean Scores for Perceived Academic Benefits of AI Use (N = 42)

S/N	Academic Dimension	Mean	SD	Interpretation
1	Research efficiency	4.09	1.14	High
2	Quality of assignments/reports	3.91	1.29	High
3	Examination preparation	3.91	1.22	High
4	Critical thinking development	3.55	1.35	High

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5	Time management	4.00	1.18	High
6	Engagement with course materials	4.00	1.34	High

Note. Interpretation scale: 1.00–2.49 = Low; 2.50–3.49 = Moderate; 3.50–5.00 = High.

Respondents rated all six academic dimensions within the high range. Research efficiency received the highest mean (M = 4.09, SD = 1.14), followed by time management and engagement with course materials (both M = 4.00). Quality of assignments/reports and examination preparation each recorded M = 3.91. Critical-thinking development recorded the lowest mean (M = 3.55, SD = 1.35), although it remained within the predefined high category. The lower relative score for critical thinking is consistent with literature cautioning that the educational value of AI depends on active and reflective engagement rather than passive acceptance of generated outputs (Kalniņa et al., 2024; Zhang et al., 2024).

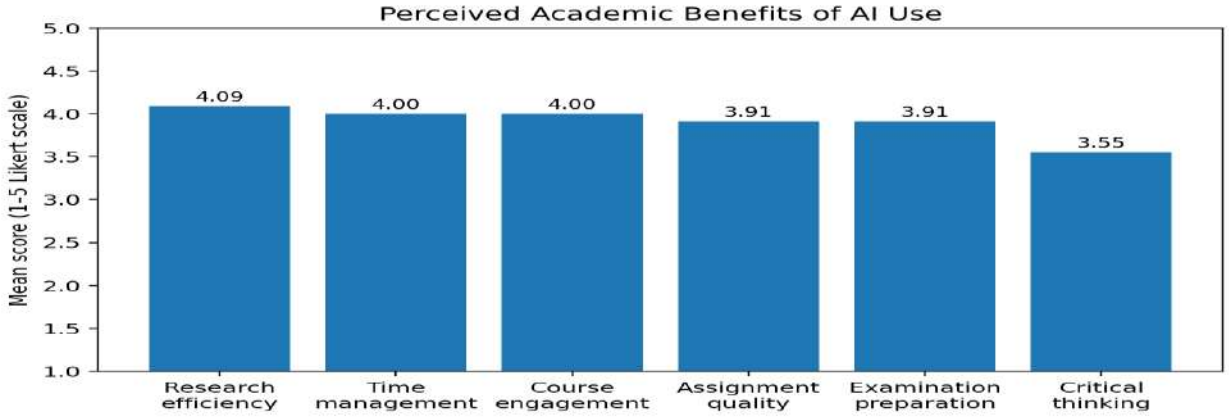


Figure 3: Perceived Academic Benefits of AI Use

Overall Self-Reported Change in Academic Performance

Table 4: Self-Reported Change in Academic Performance since Adopting AI Tools

Response	Frequency	Percentage (%)	Cumulative (%)
Yes – Improvement Observed	33	78.6	78.6
Maybe – Uncertain	6	14.3	92.9
No – No Change	3	7.1	100.0
Total	42	100	—

Note. Source: Field survey, 2025. Coding in the original analysis: Yes = 3, Maybe = 2, No = 1; M = 2.71, SD = 0.60.

Thirty-three of the 42 respondents (78.6%) reported that they had observed an improvement in their academic performance since adopting AI tools. Six respondents (14.3%) were uncertain, and three (7.1%) reported no change. These responses indicate a predominantly positive perception of AI use. They do not, however, establish that AI caused the reported improvement because no objective academic records, pre-intervention measurements, comparison group, or longitudinal design were used.

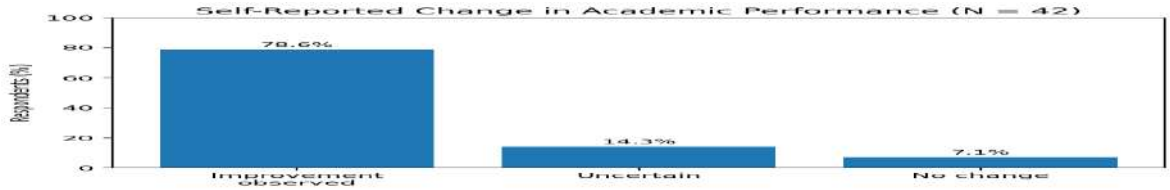


Figure 4: Self-Reported Change in Academic Performance since Adopting AI Tools (N = 42)

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Discussion of Findings

Awareness and Adoption: Evidence of an Awareness–Use Gap

The results indicate a clear difference between awareness of AI tools and their sustained academic use. Awareness was high (M = 4.38), whereas active use was moderate (M = 3.23), and participation in formal training was lower still (M = 2.82). This pattern is consistent with the proposition that awareness can diffuse more rapidly than effective adoption when institutional support, skills, or guidance are uneven (Phillips, 2025). Similar constraints relating to training, infrastructure, and uncertainty around academic use have been reported in Nigerian higher education (Abubakar et al., 2024; Ibrahim et al., 2024). The tool-category counts also show greater reporting of content-generation and language-support applications than of research assistants or reference-management tools. This may reflect differences in accessibility, familiarity, or perceived immediacy of benefit, although the present data do not directly identify the reasons for the pattern. Accordingly, these explanations should be treated as plausible interpretations rather than demonstrated causal mechanisms. From an institutional perspective, the combination of high awareness and more moderate use suggests that structured AI-literacy activities could help students move from basic familiarity towards more deliberate and academically responsible use.

Perceived Academic Benefits and the Critical-Thinking Caveat

Respondents reported positive perceptions across all six academic dimensions. Research efficiency had the highest mean, while time management, engagement with course materials, assignment quality, and examination preparation also received high ratings. These findings align with broader literature describing AI as potentially useful for feedback, drafting, tutoring, information organisation, and other forms of academic support (Wang et al., 2024; Zhang et al., 2024). Critical-thinking development received the lowest mean (M = 3.55), although it remained within the high category. Its relative position is important because it suggests that perceived gains in efficiency do not necessarily translate equally into perceived gains in higher-order reasoning. Previous research similarly cautions that AI can support critical inquiry when learners challenge, verify, and extend AI outputs, but may reduce independent engagement when outputs are accepted uncritically (Kalniņa et al., 2024; Klimova & Pikhart, 2025). Pedagogical guidance should therefore frame AI as a support for reasoning rather than a substitute for reasoning.

Implications for Practice

The findings support three practical priorities.

1. The Institute of Education could provide structured AI-literacy training that covers effective prompting, verification of AI-generated information, responsible citation, privacy, and academic integrity.
2. Students could be introduced to a broader range of digital academic-support tools rather than relying predominantly on content-generation applications.
3. Assessment practices could require students to demonstrate the reasoning, evidence, and reflective processes underlying AI-assisted work, thereby preserving the development of independent judgement.

Limitations

The findings should be interpreted in light of several limitations. The study was conducted within a single institution and involved 42 respondents, limiting the extent to which the results can be generalised to other populations. Academic outcomes were self-reported rather than measured using grades, examination scores, or other objective records. The cross-sectional design does not establish

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temporal ordering or causality. Valid response counts differed across some awareness and adoption items, but the supplied manuscript did not document the reason for these differences. The source manuscript also did not report internal-consistency statistics for the Likert scales or sufficient information to reproduce the originally stated Yamane sample-size calculation. In addition, the tool-category item contains overlapping categories and an undocumented denominator for the original percentages. Future studies should use clearly defined, mutually exclusive or explicitly multiple-response categories, document missing-data handling, report scale reliability, and where possible combine self-reported perceptions with objective academic-performance measures.

Conclusion

This study assessed AI awareness, adoption, and perceived academic benefits among Professional Diploma in Education students at the Institute of Education, Ahmadu Bello University, Zaria. The findings indicate high awareness of AI tools but more moderate active use, institutional exposure, and training. Respondents generally perceived AI as beneficial for research efficiency, time management, engagement with course materials, assignment quality, and examination preparation. Critical-thinking development received the lowest mean among the six academic dimensions, although it remained within the high interpretation category. Most respondents also reported that their academic performance had improved since adopting AI tools. These results support the value of structured institutional guidance while also underscoring the need for careful interpretation. Because the evidence is based on self-reported perceptions from a descriptive cross-sectional survey, it does not demonstrate that AI use caused academic improvement. Institutional initiatives should therefore focus not only on expanding access to AI tools but also on developing students' capacity to use them critically, ethically, and reflectively. Future research should incorporate validated scales, objective performance indicators, larger multi-institution samples, and analytical designs capable of examining associations or causal effects more rigorously.

Recommendations

1. The Institute of Education should provide structured AI-literacy training covering effective prompting, verification of AI-generated information, responsible citation, privacy, and academic integrity.
2. Students should be exposed to a wider range of academic-support tools, including research assistants and reference managers, rather than relying predominantly on content-generation applications.
3. Teaching and assessment practices should require students to demonstrate the reasoning, evidence, and reflective processes underlying AI-assisted work in order to protect the development of independent judgement and critical thinking.

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Effects of Real Objects and Posters on Academic Performance in Biology among Secondary School Students in Katsina State, Nigeria

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Abstract

This study examines the Effects of Real objects and Posters on Biology Students' Academic Performance in Secondary Schools of Katsina State. Two research objectives formulated were answered by two research questions, and two null hypotheses tested at a 0.05 level of significance. The research design for the study was quasi-experimental consist of three groups; Real objects, Posters and control groups that were randomly selected from 24 secondary schools in Katsina and adapted pretest, posttest non-Equivalent experimental control group design. The adapted biology performance test (BPT) was validated by the researcher's supervisor and other professionals in the Department of Biology and Science education. Cronbach alpha reliability coefficient of 0.71 was Obtained as the reliability coefficient of the research instrument. The data collected were analyzed by using descriptive statistics (Mean and standard deviation) and inferential statistics (Independent t-test was used for testing the null hypotheses formulated. The findings from this study revealed there is Significant difference between the experimental and control groups in terms of academic performance of the students exposed to Real object and Posters where the Real object and Picture groups significantly performed better than the control groups. The study concluded, the students who were taught using Real object and Posters elevates student learning and performance of the students in the Control group. It was recommended among others that; teachers should be supervised to ensure frequent use of Real object and Posters in their day-to-day teaching exercise.

Keywords: Academic Performance, Real object Posters, Biology

Introduction

The term Education in general is essential and basic component for attaining overall national development. It is in line with this that the National Policy on Education (FRN, 2014) states that, education should aim at the integration of individuals to become sound and effective citizens and provision of equal opportunities for all citizens of the nation. The word education comes from the Latin word e-ducere, mean "to lead out". It is indeed, difficult to define education. Education is a relentless process of becoming. To the human being we educate and to the animal we train. The development of a nation is not measured through the buildings it has built, the roads it has laid down, bridges it has constructed but by the human resources, the nation has developed through a well-defined system of education. Although the physical facilities are usually important, they are perishable and valuable. In the absence of proper education, the nation can hardly develop these and maintain them. Science Education deals with sharing of science contents and process with individuals who are not primarily considered to be member of the scientific community in order for them to understand science and utilize such knowledge for self and others benefit. Generally, members not part of scientific community consists of individuals who could be students, farmers, market women or a whole community Arlington, (2017). However, science education as conceived in

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the context of this paper has to do with students undergoing training in sciences, be it in secondary or tertiary institutions of learning. Science education could be viewed as a process of teaching or training especially, within the school system to improve one's knowledge about the environment and to develop one's skill of systematic enquiry as well as natural attitudinal characteristics. Biology as a branch of the general body of knowledge (science), has been defined by different scientists according to perception and understanding of the subject. Okwo (2020) define Biology as a science which involves systematic study of living things and interaction with each other and their environment. Kalu (2023) simply defines Biology as the science of life. Biology as a science of life is concerned with the characteristics of living things, their forms, functions and relationship with one another and with their environment among others. However, for effective Biology teaching, the use of Real object and Posters which would make the use of the environment would achieve much and bring home the actual meaning of Biology. Biology is one of the elective subjects in the Key Learning Area (KLA) of Science Education.

Academic performance refers to as the level at which a student, teacher or institution has managed to reach their educational goals. Academic Performance is the extent to which a learner is profiting from instructions in a given area of learning, that is to say that achievement is reflected by the extent to which skill or knowledge has been imparted to him. In relation to skills acquisition, Adebule (2016) observes that improving students' abilities, and fostering student's scientific literacy are the ultimate goal of Biology. In order to achieve the goal, some steps must be taken such as training students to acquire science process skills. Real object is a teaching material method that uses real-life objects, artefacts, or materials to enhance students' learning experiences. These objects can be anything from everyday items like coins, maps, or newspapers to specialized things like scientific equipment or cultural artefacts. Real object are objects from real life used to improve students' understanding of other cultures and real-life situations in classroom instruction (Aggarawal 2018). Real object refers to authentic objects from real life that one uses in the classroom to teach a specific concept. Real object can be both physical and virtual, as long as it is something used in the real world. It can make the learning experience more memorable and create connections between objects and topic of discussion. One of the benefits of using Real object in classroom is that, it helps make it easier for young learners to recall information. A Picture is a temporary promotion of an idea, product, or event put up in a public space for mass consumption. Typically, Posters include both textual and graphic elements, although a Picture may be either wholly graphical or wholly text. Posters are designed to be both eye-catching and informative. Posters may be used for many purposes. They are a frequent tool of advertisers (particularly of events, musicians, and films), propagandists, protestors, and other groups trying to communicate a message. Posters are also used for reproductions of artwork, particularly famous works, and are generally low-cost compared to the original artwork. The modern Picture, as we know it, however, dates back to the 1840s and 1850s when the printing industry perfected colour lithography and made mass production possible. Picture can highly effective in humanities sources and have been shown to improve metacognitive practice too (Musah 2017).

Statement of the Problem

This study is inspired in response to students' persistent poor performance in some Areas in Biology. Perhaps this can be partly ascribed to inadequate teaching and instructional methods adopted by Biology teachers. Students' failure in Senior Secondary School West Africa Examination Council (WAEC) and National Examination Council (NECO) is becoming rampant in which only few candidates obtain the requirement for further studies into Nigerian higher institutions. Therefore, learners need to be instructed using proper instructional materials, regarding the teaching and

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learning process. This prompted the desire to investigate how the REAL OBJECT and Posters will be used in teaching and learning of the concept of Digestive system in biology among Senior Secondary Schools in Katsina Zonal Education Quality Assurance, Katsina State, Nigeria.

Objectives of the Study

The following objectives were set to guide the study:

1. Determine the effect of Real object on Biology students' academic performance in secondary school in secondary school
2. Examine the effect of Posters on Biology students' academic performance in secondary school

Research Hypothesis

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

1. There is no significant difference in mean students' academic performance scores when taught the Digestive system using Real object and those taught with the conventional method in secondary school.
2. There is no significant difference in mean students' academic performance scores when taught Biology using Posters and those taught with conventional method in secondary school.

Research Methodology

This study employed a pre-test post-test quasi-experimental, control group design. There are three groups. The first group is the experimental group one (EG_1) was treated using real object, the second group is the experimental group two (EG_2) which was treated using posters while the last group is the control (CG) that was exposed to conventional method. All the three groups were pretested (0_1) to ensure the participants are not significantly different in academic performance. The two experimental groups that received treatment (X_1) were post tested (0_2) to determine the effect of treatment on students' academic performance

Population and Sample

The population for this study consisted of all Senior Secondary School two (SSII) Biology students in Katsina zonal education quality assurance. The schools consisted of all of public schools that offer Biology within the Katsina zonal education quality assurance. The schools consist of one (1) all boys school, two (2) all-girls school and twenty-one (21) co-educational secondary schools that make twenty-four (24) schools in all. The number of male students was 8,748 and female students has 7,174 making a total population of 15,922, all the schools have the same characteristics in terms of ownership, calendar, syllabus and scheme of work. The sample of the study covered a total number of 125 SSII students comprised 67 males and 58 females from the 3 public senior secondary schools in Katsina. To select a representative sample for this study, the education zone was clustered in three local Government Areas. From each of the cluster, a simple random sampling technique was used and three sampled schools from the list of the co-educational schools only thereby isolating the single-gender schools. The random sampling was carried out using balloting. Intact classes were placed as the first experimental, second experimental and control group.

Instrument for Data Collection

The instrument used for data collection is Biology performance Test (BPT) which consist of 25 items multiple choice question lettered A-D. The items were obtained from a collection of West African Examination Council (WAEC) and National Examinations Council (NECO) past assessment items on Biology. The items cover the entire unit taught by the researcher on the area of Digestive System and are in line with the National Biology Syllabus for SSII. To ascertain the validity of the adapted BPT, the researcher submitted the initial draft of BPT to the researcher's supervisor and other professionals in the department of education for content as well as face validity. The

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recommendations made by these experts were used to modify the final version of the instrument. The instrument's reliability coefficient 0.71 was determined through the use of Cronbach Alpha and it ensured the measurement of internal consistency of the instrument to be use. The responses of the students in the Biology Performance Test (BPT) were scored using the marking scheme. The research questions were answered using descriptive statistics (Mean and standard deviation) while the null hypotheses were tested at 0.05 level using inferential statistics. Specifically, null hypotheses 1&2 were tested using independent sampled t-test. The choice for independent t-test is due to the fact that, t-test assesses significant difference between independent groups.

Presentation of Results

Hypothesis One

There is no significant difference in mean students' academic performance scores when taught Digestive system using Real object and those taught with conventional method in secondary school.

Table 1: t-test Analysis of Academic Performance of Students taught Biology using Real object and those taught using conventional method

Table 1: t-test Analysis between Students' performance in Experimental and Control Groups 1

Grouping	N	Mean	Std. Deviation	T	Df	p-value	Decision
Posters	73	69.45	15.10	7.68	140	<0.001	Significant
Control	69	47.55	18.76				

Significant at *P* is less than 0.05

Table 1 presents the t-test Analysis of academic performance of Biology students taught using Real object method. From the results, the t-value recorded is 7.68 while the p-value calculated at degree of freedom of 140 is 0.001. P-value is less than 0.05 and therefore null hypothesis which stated that there is no significant difference in mean students' academic performance scores when taught Biology using Real object and those taught with conventional method is rejected. There for students taught using Real object performed significantly better than those taught using conventional method.

Hypothesis two

There is no significant difference in mean students' academic performance scores when taught Biology using Posters and those taught with conventional method in secondary school.

Table 2: t-test Analysis of Academic Performance of Students taught Digestive system using Posters and those taught using conventional method

Table 2: t-test Analysis between Students' performance in Experimental and Control Groups 2

Grouping	N	Mean	Std. Deviation	t	df	p-value	Decision
Posters	73	69.45	15.10	7.68	140	<0.001	Significant
Control	69	47.55	18.76				

Significant at *P* is less than 0.05

Table 2 presents t-test Analysis of academic performance of Biology students taught using Posters method. From the results, the t-value recorded is 7.68 while the p-value calculated at degree of freedom of 74 is 0.001. P-value is less than 0.05 and therefore null hypothesis which stated that there is no significant difference in mean students' academic performance scores when taught Biology using Posters and those taught with conventional method is rejected. Therefore, students taught using Posters performed significantly better than those taught using conventional method.

Summary of the Findings

From the result presented in this study, the summary of the major findings as follows:

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1. Students taught using Real objects recorded the highest mean score than students exposed to conventional method. Therefore, there is significant difference in mean students' Academic performance scores when taught Digestive system using Real objects and those taught with conventional method.
2. Students taught using Posters recorded the highest mean score than students exposed to conventional method. Therefore, there is significant difference in the mean students' Academic performance scores when taught Digestive system using Posters and those taught with conventional method.

Discussion of Findings

The study reveals that there is significant effect of Real object and Posters on students' Academic performance in biology. Both Real object and Posters have equal potential to elevate students' academic performance in biology. This finding corroborates with numerous previous studies on the effect of Real object and Posters and other instructional materials across various subjects taught in secondary schools.

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Correlationship Between Pre-School Teachers' Grit and Work Engagement among Nursery Schools in Benin City, Edo State, Nigeria

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Abstract

The psychological characteristics of preschool teachers may shape their capacity to sustain effective involvement in the demanding work of educating and caring for young children. This study investigated preschool teachers' grit as a correlate of work engagement in nursery schools in Benin City, Edo State, Nigeria. Specifically, it examined the relationship between teachers' grit and work engagement and determined whether age and years of teaching experience moderated this relationship. A correlational research design was adopted. The population comprised 284 preschool teachers in registered public and private nursery schools in Benin City, from which 98 teachers were selected using a multistage sampling procedure. Data were collected using a structured questionnaire measuring grit, specifically perseverance of effort and consistency of interests, and work engagement, comprising vigour, dedication and absorption. The instrument was validated by experts and yielded a Cronbach's alpha reliability coefficient of 0.79. Data were analysed using Pearson Product-Moment Correlation and moderation analysis at the 0.05 level of significance. Findings revealed a positive and statistically significant relationship between preschool teachers' grit and work engagement ($r = 0.61$, $p = .001$). However, age did not significantly moderate the relationship ($\beta = 0.07$, $p = .455$), and neither did years of teaching experience ($\beta = 0.06$, $p = .504$). The study concludes that grit is an important personal correlate of preschool teachers' work engagement, with the relationship not significantly varying by age or teaching experience. It recommends integrating psychological resource development, particularly perseverance and sustained commitment, into teacher professional development programmes.

Keywords: Preschool Teachers; Grit; Work Engagement; Age; Teaching Experience; Nursery Schools

Introduction

Early childhood education occupies a foundational position in the educational development of every child. The preschool years represent a particularly important period during which children develop basic cognitive abilities, language and communication skills, social competence, emotional regulation, physical coordination, curiosity and attitudes towards learning. Experiences provided during these formative years can influence children's subsequent adjustment to formal schooling and their capacity to participate meaningfully in learning activities. Consequently, the quality of early childhood education cannot be separated from the quality, disposition and professional functioning of the teachers who work directly with young children. Preschool teachers are not merely transmitters of academic knowledge; they serve simultaneously as caregivers, facilitators, role models, classroom managers, observers of children's development and significant adults in children's early social environments. Their psychological readiness and willingness to invest sustained effort in their work are therefore important considerations in achieving quality early childhood education. The centrality of the teacher in early childhood education is particularly pronounced because young children require continuous attention, patience, encouragement, supervision and emotional responsiveness. Unlike older learners who may be expected to demonstrate relatively greater independence, preschool

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children often require teachers to provide repeated instructions, redirect their attention, respond to individual differences, manage emotional outbursts, facilitate peer interactions and create opportunities for learning through play and exploration. Teachers are consequently required to expend considerable physical, cognitive and emotional resources during the school day. They must simultaneously attend to the developmental needs of individual children while meeting curriculum expectations, maintaining classroom order, communicating with parents and complying with school policies. The demanding nature of these responsibilities makes teachers' psychological resources an important area of educational inquiry. In Nigeria, and Edo state in particular, the importance of early childhood education is recognised within the broader national educational system. Nevertheless, the sector continues to experience challenges that can affect the quality and effectiveness of educational provision. Literature on early childhood education in Nigeria has identified concerns including inadequate infrastructure and instructional resources, insufficient funding, uneven implementation of curriculum provisions, insufficiently qualified personnel and weaknesses in regulation and quality assurance. Such challenges may place considerable demands on teachers and may influence how they perceive and perform their occupational responsibilities. In this environment, attention to teachers' individual psychological strengths becomes important because teachers may differ considerably in their capacity to sustain effort, remain committed to professional goals and continue functioning effectively when confronted with difficulties.

The concept of grit has emerged as an important construct within the field of positive psychology and educational research. Grit generally refers to sustained passion and perseverance towards long-term goals, particularly the willingness to maintain effort and commitment despite obstacles, setbacks or periods of difficulty (Boyle, Hood, & Bradley, 2017). Unlike temporary motivation, grit concerns persistence over time (Babiera, & Quirap, 2024). It therefore provides a useful lens through which individual differences in teachers' responses to occupational challenges can be understood. A teacher may encounter a difficult class, inadequate teaching resources, demanding parents, heavy workload, limited administrative support or repeated behavioural challenges. While such experiences may reduce motivation for some individuals, a teacher with a stronger disposition towards perseverance may continue to pursue professional goals and maintain effort despite these difficulties. Datu (2021) explained that grit is commonly conceptualised around two related dimensions: perseverance of effort and consistency of interests. Perseverance of effort concerns the tendency to continue working towards an objective even when progress is difficult or setbacks occur. Consistency of interests concerns the capacity to maintain commitment to important goals rather than frequently abandoning them for new pursuits. In the context of preschool teaching, both dimensions may have practical relevance. Teaching young children requires teachers to repeatedly engage in activities that may not produce immediate results. A teacher may need to teach the same concept several times, modify an activity for a child who is experiencing difficulty, develop alternative strategies for managing behaviour or repeatedly encourage a child who is reluctant to participate. The willingness to continue such efforts may be associated with the teacher's level of grit. The relevance of grit to teaching becomes clearer when the nature of preschool education is considered (Duckworth et al., 2007). Effective preschool teaching requires patience and sustained commitment because children's developmental progress is often gradual and heterogeneous. Two children exposed to the same learning experience may respond differently because of differences in language development, cognitive ability, temperament, family background and previous experiences. Teachers therefore have to adjust their approaches and persist until children receive appropriate support. A teacher who expects immediate results may become frustrated when children do not respond as anticipated.

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In contrast, a teacher with a stronger capacity for perseverance may interpret difficulties as challenges requiring additional effort, adaptation and professional reflection. Grit may therefore constitute a personal resource that helps teachers maintain goal-directed behaviour in demanding educational environments. Fabelico, and Afalla, (2020) explained that grit represents one individual-level characteristic that may interact with the conditions under which teachers work. A high level of grit may help a teacher persist in challenging circumstances, but the availability of supportive organisational resources remains essential for sustainable professional functioning. Closely related to the issue of teachers' psychological functioning is the concept of work engagement.

Kim, and Kim (2023) expressed that work engagement refers to a positive, fulfilling and work-related psychological state generally characterised by vigour, dedication and absorption. Vigour involves high levels of energy and mental resilience while working; dedication reflects a sense of significance, enthusiasm, inspiration, pride and challenge; while absorption involves being fully concentrated and deeply engrossed in one's work. In educational settings, an engaged teacher is therefore expected to demonstrate energy in carrying out teaching responsibilities, enthusiasm for the profession and sustained psychological involvement in classroom activities. Work engagement is particularly important in nursery schools because teaching young children requires more than the mechanical delivery of lessons. Teachers have to be emotionally present and responsive to children's needs. They need to listen, observe, encourage, comfort, stimulate curiosity and participate actively in children's learning experiences. A teacher who is physically present but psychologically disengaged may fulfil basic duties without demonstrating the level of enthusiasm, creativity and responsiveness required for high-quality early childhood practice. Conversely, an engaged teacher is more likely to approach classroom responsibilities with energy, demonstrate commitment to children's development and become immersed in activities that support learning. The importance of teacher work engagement extends beyond the teacher as an individual (Hodge, Wright, & Bennett, 2020). Teachers' engagement may influence the quality of the classroom environment and the experiences children receive. The relationship between grit and work engagement can also be understood from the perspective of teachers' capacity to sustain effort towards meaningful professional goals (Suzuki, Tamesue, Asahi, & Ishikawa, 2015). Work engagement involves energy, dedication and absorption in current work activities, while grit concerns sustained effort and commitment towards longer-term goals. Although the two constructs are conceptually distinct, they share an important emphasis on persistence and goal-directed behaviour (Biglete, 2025). A gritty preschool teacher may remain committed to improving children's learning and development even when classroom experiences are demanding. Such persistence may help the teacher maintain vigour and dedication in daily work activities. In turn, sustained engagement may reinforce the teacher's sense of purpose and commitment to teaching. Also, a teacher can be present in the classroom without being genuinely engaged. Work engagement concerns the quality of the teacher's psychological involvement in work. An engaged preschool teacher is likely to invest energy in lesson preparation, interact actively with children, respond thoughtfully to individual needs, collaborate with colleagues, reflect on teaching experiences and demonstrate dedication to the educational development of children. Therefore, identifying personal characteristics associated with engagement may help educational administrators understand how teachers can be better supported.

Grit may be particularly relevant because preschool teaching requires persistence in the face of repeated and sometimes unpredictable challenges. Consider, for example, a teacher working with a child who has difficulty communicating, following instructions or interacting appropriately with

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peers. The teacher may need to observe the child carefully, communicate with parents, modify classroom activities, employ alternative instructional strategies and monitor progress over an extended period. Similar persistence may be required when managing classroom behaviour, introducing new teaching approaches or addressing learning difficulties. The capacity to continue pursuing meaningful educational goals despite temporary setbacks is consistent with the core idea of grit. Nevertheless, it is important to distinguish grit from mere endurance or compliance. A teacher who remains in a job because of economic necessity is not necessarily gritty in the psychological sense. Similarly, a teacher who completes routine duties without enthusiasm cannot automatically be described as highly engaged. Grit concerns sustained effort and commitment towards valued long-term goals, whereas work engagement concerns the positive quality of one's psychological relationship with current work (Branzuela, 2025). This conceptual distinction makes the examination of their relationship scientifically worthwhile. The study is not simply asking whether hardworking teachers are engaged; it seeks to determine whether a specific psychological characteristic; grit is systematically related to a specific occupational state; work engagement. In further details, Baustista and Delararte (2025) directly examined the moderating effects of age and years of experience or career stage on the relationship between grit and work engagement among public school teachers, their findings indicated that older teachers tended to report higher engagement and that career stage significantly moderated the grit-work engagement relationship. Furthermore, a recent study involving 529 preschool teachers found that teachers with extensive teaching experience were more likely to maintain high work engagement, suggesting that accumulated professional experience may constitute an important resource for sustaining engagement (Crede, Tnade, & Borman, 2017; Hodge, Wright, &Bennett, 2020).

Despite the growing international literature on teacher grit and work engagement, an important gap remains. Much of the available empirical literature has focused on teachers in general education, foreign language education or contexts outside Nigeria. Relatively fewer studies have specifically examined preschool teachers' grit and work engagement, particularly within Nigerian nursery schools. Even where early childhood research has considered teacher stress, workplace conditions or instructional quality in Benin City, there remains a need to investigate positive psychological resources such as grit and their relationship with teachers' engagement. The present study is consequently anchored in the assumption that teachers are not passive recipients of workplace conditions but individuals who possess psychological characteristics that may influence how they respond to occupational demands. Grit may enable some teachers to maintain effort and commitment despite difficulties, while work engagement reflects the extent to which those teachers experience energy, dedication and absorption in their professional activities. However, the strength and nature of the relationship between these constructs among preschool teachers in Benin City cannot be determined theoretically; it requires empirical investigation. It is against this background that the study wants to investigate the preschool teachers' Grit as Correlates of Work Engagement in Nursery Schools in Benin City. Despite the demanding nature of preschool teaching and the importance of teachers' psychological resources, there is insufficient empirical evidence on whether preschool teachers' grit is associated with their work engagement in nursery schools in Benin City. Teachers working under similar conditions may differ in their ability to sustain effort, remain committed to professional goals and maintain vigour, dedication and absorption in their work. Although studies have reported associations between grit and work engagement among teachers in other educational contexts, limited attention has been given to preschool teachers in Nigeria. Furthermore, it remains unclear whether teachers' age and years of teaching experience influence

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the strength of the relationship between grit and work engagement. This gap in evidence makes it necessary to empirically examine the relationship between preschool teachers' grit and work engagement and determine whether age and years of teaching experience moderate this relationship in nursery schools in Benin City.

Objectives of the Study

The main objective of this study is to investigate preschool teachers' grit as a correlate of work engagement in nursery schools in Benin City, Edo State, Nigeria. Specifically, the study seeks to:

1. determine the relationship between preschool teachers' grit and their work engagement in nursery schools in Benin City;
2. determine whether age moderates the relationship between preschool teachers' grit and their work engagement in nursery schools in Benin City; and
3. determine whether years of teaching experience moderates the relationship between preschool teachers' grit and their work engagement in nursery schools in Benin City.

Null Hypotheses

The following hypotheses were formulated and tested at the 0.05 level of significance:

Ho_1: There is no significant relationship between preschool teachers' grit and their work engagement in nursery schools in Benin City

Ho_2: Age does not significantly moderate the relationship between preschool teachers' grit and their work engagement in nursery schools in Benin City.

Ho_3: Years of experience do not significantly moderate the relationship between preschool teachers' grit and their work engagement in nursery schools in Benin City.

Research Methodology

The study adopted a correlational research design. The design is appropriate because the study seeks to determine the nature and magnitude of the relationship between preschool teachers' grit and their work engagement without manipulating any of the variables. The correlational survey design allows for the collection of data from a representative sample of preschool teachers in their natural school settings (Creswell, & Creswell, 2018). The independent variable is preschool teachers' grit, while the dependent variable is preschool teachers' work engagement. The population comprised all preschool teachers in registered public and private nursery schools in Benin City. Specifically, the target population consisted of estimated 284 teachers handling Nursery one, Nursery two and nursery three (Edo State Universal Basic Education Board, 2026). A multistage sampling procedure was employed to select participants. At the first stage, nursery schools in Benin City were stratified according to school ownership (public and private). At the second stage, 12 schools were selected from the respective strata using proportionate stratified random sampling. At the third stage, 98 eligible teachers were selected using simple random sampling by balloting. Participation was voluntary, and only teachers who provide informed consent were included. Data was collected using a structured questionnaire comprising three sections. Section A obtained demographic information of the respondents, particularly age and years of teaching experience. Section B measured teachers' grit, particularly perseverance of effort and consistency of interests, using an adapted grit instrument developed by Angele Duckworth and Quinn, P.D (2009). Section C measured work engagement using an adapted Utrecht work Engagement Scale (UWES) as developed by Schaufeli, W & Bakker, A. (2006) assessing vigour, dedication and absorption. Higher scores will indicate higher levels of the respective constructs. The instrument was subjected to appropriate validation procedures. Three copies of the questionnaire, together with the research objectives, research questions and hypotheses, were submitted to experts in Early Childhood Education, Educational Psychology

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including Measurement and Evaluation. The experts examined the instruments for relevance, clarity, adequacy of coverage, appropriateness of language and alignment with the constructs being measured. Their recommendations were incorporated before final administration. A pilot test was conducted among preschool teachers who are similar to, but will not form part of, the main study participants. The responses were analysed using Cronbach's alpha to establish internal consistency reliability. A coefficient of 0.79 was obtained which was considered acceptable and reliable for the research purposes. Necessary approval was obtained from relevant educational authorities and school administrators. Permission was also sought from the heads or proprietors of selected nursery schools. The researcher and four trained research assistants explained the purpose and procedures of the study to eligible teachers. Participation was entirely voluntary, informed consent was obtained, and questionnaires were administered and retrieved using procedures designed to maximized response rates and protect confidentiality. Data collected were coded and analysed using the SPSS version 26. Pearson Product-Moment Correlation Coefficient (r) was used to test the first hypothesis concerning the relationship between grit and work engagement at the 0.05 level of significance. Moderation analysis was used to determine whether age and years of teaching experience significantly moderate the relationship between grit and work engagement.

Presentation of Results

Ho_1: There is no significant relationship between preschool teachers' grit and their work engagement in nursery schools in Benin City.

Pearson Product-Moment Correlation Coefficient was used to determine the relationship between preschool teachers' grit and work engagement. The result is presented in Table 1.

Table 1: Pearson Product-Moment Correlation between Preschool Teachers' Grit and Work Engagement

Variables	N	Mean	SD	r	p-value	Decision
Grit	98	3.47	0.39	0.61	0.001	Significant
Work Engagement	98	3.58	0.41			

The result in Table 1 indicates that preschool teachers' grit had a moderate positive and statistically significant relationship with their work engagement ($r = 0.61$, $p = 0.001$). Since the p-value of 0.001 is less than the 0.05 level of significance, the null hypothesis was rejected. This means that there is a significant positive relationship between preschool teachers' grit and work engagement in nursery schools in Benin City. The positive correlation indicates that teachers who reported higher levels of grit tended, on average, to report higher levels of work engagement. The magnitude of the correlation ($r = 0.61$) suggests a moderate association between the two variables.

Ho_2: Age does not significantly moderate the relationship between preschool teachers' grit and their work engagement in nursery schools in Benin City.

Moderation analysis was conducted to determine whether age significantly changes the relationship between grit and work engagement. The result is presented in Table 2.

Table 2: Moderating Effect of Age on the Relationship between Grit and Work Engagement

Predictor	B	SE	B	t	p-value
Grit	0.48	0.10	0.45	4.80	<0.001
Age	0.06	0.05	0.12	1.20	0.233
Grit × Age	0.03	0.04	0.07	0.75	0.455

$R^2 = 0.23$; $\Delta R^2 = 0.01$; $F = 9.42$; $p < 0.001$.

The result in Table 2 shows that the interaction between grit and age was not statistically significant ($\beta = 0.07$, $p = 0.455$). Since the p-value is greater than 0.05, the null hypothesis was not rejected.

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This indicates that age does not significantly moderate the relationship between preschool teachers' grit and work engagement. Although grit significantly predicted work engagement within the moderation model (β = 0.45, p < 0.001), the interaction between grit and age was not significant. Thus, the positive relationship between grit and work engagement appears to be relatively consistent across the age groups represented in the study.

Ho_3: Years of experience do not significantly moderate the relationship between preschool teachers' grit and their work engagement in nursery schools in Benin City.

Moderation analysis was conducted to determine whether years of teaching experience significantly changes the relationship between grit and work engagement. The result is presented in Table 3.

Table 3: Moderating Effect of Years of Teaching Experience on the Relationship between Grit and Work Engagement

Predictor	B	SE	B	t	p-value
Grit	0.46	0.10	0.43	4.60	<0.001
Years of Experience	0.05	0.04	0.11	1.25	0.215
Grit × Years of Experience	0.02	0.03	0.06	0.67	0.504

$R^2 = 0.22$; $\Delta R^2 = 0.01$; $F = 8.97$; $p < 0.001$.

The result in Table 3 indicates that the interaction between grit and years of teaching experience was not statistically significant (β = 0.06, p = 0.504). Since the p-value is greater than 0.05, the null hypothesis was not rejected. This implies that years of teaching experience does not significantly moderate the relationship between preschool teachers' grit and work engagement. The result suggests that the positive association between teachers' grit and work engagement remains relatively similar regardless of the number of years teachers have spent in the teaching profession.

Discussion of Findings

The finding revealed a moderate positive and statistically significant relationship between preschool teachers' grit and work engagement (r = 0.61, p = 0.001). This indicates that teachers who demonstrated higher levels of perseverance and sustained commitment to their professional goals also tended to demonstrate higher levels of vigour, dedication and absorption in their work. This finding is consistent with the findings of Suzuki, Tamesue, Asahi, and Ishikawa, (2015); Biglete, (2025) that grit demonstrate a positive correlation with work engagement of teachers, which further explained that as grit of teacher increases their quest to further engage in the work activities of teaching increases. Grit concerns sustained passion and perseverance towards long-term goals, while work engagement reflects a positive psychological state characterized by vigour, dedication and absorption. Although the constructs are conceptually distinct, both involve sustained effort and goal-directed behaviour. The finding may be explained by the demanding nature of preschool teaching. Nursery teachers are expected to provide continuous attention, patience, encouragement and supervision while responding to individual differences among children. They may need to repeat instructions, modify learning activities, manage behavioural difficulties and provide sustained encouragement before desired developmental outcomes become evident. Teachers with stronger perseverance may therefore be more capable of maintaining psychological involvement when immediate results are not achieved.

The finding further suggests that grit may function as an important personal psychological resource for preschool teachers. An engaged teacher is expected to demonstrate energy, enthusiasm and

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psychological involvement in classroom activities, while a gritty teacher is more likely to persist in the pursuit of valued goals despite obstacles. The combination of these characteristics may therefore contribute to sustained involvement in preschool teaching. The result is particularly important within the context of nursery education because teachers may encounter demanding parents, inadequate resources, heavy workloads, behavioural challenges and differences in children's developmental needs. Under such conditions, perseverance may help teachers maintain their commitment and effort rather than withdraw psychologically from their work. However, the finding should not be interpreted as evidence that grit causes work engagement. The study employed a correlational research design, which is appropriate for determining the nature and magnitude of relationships between variables without manipulating them. Thus, the finding establishes an association rather than a causal effect.

Moderating Effect of Age

The finding revealed that age did not significantly moderate the relationship between preschool teachers' grit and work engagement (β = 0.07, p = 0.455). This means that the relationship between grit and work engagement did not differ significantly according to teachers' age. Within the sample studied, age did not significantly alter the relationship between grit and work engagement. This may be explained by the common demands of preschool teaching. Irrespective of age, nursery teachers are required to demonstrate patience, respond to children's individual differences, manage classroom behaviour and sustain attention throughout the school day.

The finding also supports the view of Bautista and Delariarte, (2025) that grit represents an individual psychological characteristic that may operate across different categories of teachers' ages but do not show considerable distinction to the revealed relationship between grit and work engagement among preschool teachers

The non-significant moderation effect of age therefore suggests that age does not substantially alter the relationship between grit and work engagement among the teachers studied. Nevertheless, age may still have independent relationships with other aspects of teachers' professional functioning; the present finding specifically concerns its moderating role in the grit–work engagement relationship.

Moderating Effect of Years of Teaching Experience

The finding showed that years of teaching experience did not significantly moderate the relationship between preschool teachers' grit and work engagement (β = 0.06, p = 0.504). This indicates that the association between grit and work engagement was not significantly different for teachers with varying levels of teaching experience. One possible explanation is that the psychological importance of perseverance may not depend substantially on the number of years a teacher has spent in the profession. Both newly employed and highly experienced preschool teachers encounter situations requiring patience, persistence, adaptation and continued engagement with children's developmental needs. The finding is also consistent with the findings of Crede, Tnade, and Borman, (2017); Hodge, Wright, and Bennett, (2020) which revealed that years of experience, though important do not moderate the relationship between teachers' grit and work engagement. The result further implies that schools should not assume that experienced teachers will automatically possess greater work engagement or that less experienced teachers will necessarily be less engaged. Rather, individual psychological characteristics such as grit may be relevant across different levels of professional experience.

Conclusion

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Overall, the study concludes that preschool teachers' grit is positively and significantly associated with their work engagement in nursery schools in Benin City. However, age and years of teaching experience did not significantly moderate this relationship. The findings highlight the relevance of teachers' psychological characteristics, particularly their perseverance and sustained commitment to professional goals, in understanding work engagement. Nevertheless, grit should not be considered in isolation, as teachers' engagement may also be shaped by the organisational and working conditions within which they perform their professional responsibilities.

Recommendation

Based on the findings of the study, the following recommendations are made:

1. School administrators should incorporate psychological resource development into teacher professional development programmes. Particular attention should be given to strengthening perseverance, sustained commitment to professional goals and constructive responses to workplace challenges, as grit was found to be positively associated with teachers' work engagement.
2. Nursery school proprietors and administrators should provide supportive working environments that promote sustained teacher engagement. Adequate teaching and learning resources, manageable workloads, supportive supervision, recognition of teachers' efforts and opportunities for professional development should complement teachers' personal psychological resources.
3. Teacher education institutions should give greater attention to positive psychological competencies in the preparation of preschool teachers. Alongside pedagogical knowledge and classroom-management skills, prospective teachers should be exposed to strategies for developing perseverance, professional commitment, adaptive responses to challenges and sustained engagement with children's developmental needs.

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Assessment of Local Government Administration on Socio-Economic Development in Otukpo Local Government Area, Benue State, Nigeria

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Abstract

Despite the establishment of local governments as grassroots institutions for promoting economic and social development, many local councils continue to experience challenges such as poor implementation of development programmes, corruption, inadequate funding, and weak institutional capacity, all of which hinder effective development outcomes. Consequently, this study examined local government administration and socio-economic development in Otukpo Local Government Area. The population comprised 150 staff members of the local government council, from which 109 respondents were randomly selected. The study was guided by two research questions and two corresponding hypotheses tested at the 0.05 level of significance. A survey research design was adopted, and data were collected using a structured questionnaire. The instrument was face-validated and yielded a reliability coefficient of 0.68. Descriptive statistics, including frequency counts and percentages, were used to answer the research questions, while the Pearson Product–Moment Correlation was employed to test the hypotheses. The results indicated that there is a significant relationship between local government administration and socio-economic development in Otukpo Local Government Area. The study also found a significant relationship between the identified solutions and the improvement of local government administration and socio-economic development in the study area. The study recommends strengthening institutional capacity and enhancing the effective implementation of development programmes to promote sustainable socio-economic development in Otukpo Local Government Area.

Keywords: *Local Government Administration, Economic & Socio-economic Development,*

Introduction

Local government administration occupies a strategic position in Nigeria's governance structure, particularly in promoting economic and socio development at the grassroots level. As the tier of government closest to the people, local government is entrusted with the responsibility of identifying community needs and implementing development initiatives that directly affect citizens' daily lives (Pius, 2022). Through the provision and maintenance of basic infrastructure such as rural roads, water supply, electricity, markets, and primary healthcare facilities, local governments create an enabling environment for socio-economic activities. These infrastructural interventions enhance mobility, improve business operations, and increase access to essential services, thereby stimulating local economic growth (Igbokwe, 2018). Despite the strategic role of local governments, the socio-economic development of Otukpo Local Government, has continued to face significant challenges. These challenges have constrained development efforts and adversely affected the quality of life of residents (Zakari, 2019). Many rural communities lack adequate road networks, experience irregular electricity supply, and suffer from limited access to clean and potable water. These deficiencies pose serious public health risks and undermine

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overall socio-economic well-being (Ogbazi, 2019). The education sector also faces notable challenges, as many schools operate with inadequate infrastructure, insufficient instructional materials, and a shortage of qualified teachers. Although tertiary institutions exist within the area, their limited capacity restricts access to higher education for many local students, thereby reducing opportunities for human capital development. Similarly, the healthcare system is constrained by a limited number of health facilities, inadequate medical equipment, and a shortage of trained personnel. Poor infrastructure further limits access to healthcare services in rural communities, negatively affecting maternal and child health outcomes and the control of preventable diseases (Mark, 2019). Governance-related issues have further weakened the effectiveness of local government administration in Otukpo LGA. Musa (2024) observed that local governments in Nigeria have increasingly been reduced to caretaker institutions under the control of state governments. The frequent use of caretaker committees and the absence of genuinely democratic local government elections have reinforced authoritarian control by state governors over local councils (Okoli, 2020).

In Otukpo LGA, changes in leadership are often accompanied by the dissolution or reconstitution of council officials, whether elected or appointed, primarily as a strategy to consolidate political support rather than to enhance administrative efficiency (Mark, 2019). Such practices undermine continuity in policy implementation and weaken institutional capacity for sustainable development. Addressing these challenges requires deliberate and proactive strategies by local government authorities. One critical intervention is the strengthening of agricultural development through the engagement of agricultural extension officers to disseminate modern farming techniques to local farmers. This approach enhances productivity, promotes food security, and supports rural livelihoods through improved agricultural yields (Denga, 2018). Furthermore, increased financial allocations from federal and state governments are essential to enable local governments to effectively deliver primary education and healthcare services. Internally, local governments must also improve revenue generation mechanisms and ensure prudent financial management to support developmental projects that enhance living standards at the grassroots level. The adoption of direct labour in project execution, rather than excessive reliance on contractors, can reduce costs and free up resources for additional development initiatives (Bass, 2008). Such measures have the potential to reduce rural–urban migration by improving socio-economic conditions within local communities. Although several studies have examined the role and impact of local government administration in Nigeria, there is a noticeable gap in empirical research focusing specifically on economic and social development in Otukpo Local Government Area of Benue State. This paper therefore seeks to fill this gap by providing a focused analysis of local government administration and its contributions to socio-economic development in the area.

Statement of the Problem

Despite various reform initiatives aimed at strengthening local government administration and enhancing grassroots development in Nigeria, socio-economic development at the local government level remains largely unsatisfactory. Persistent challenges such as inadequate funding, shortage of skilled manpower, weak internally generated revenue, corruption, poor accountability, policy inconsistency, and limited community participation continue to hinder effective service delivery and sustainable development outcomes (Chiliokwu, 2018). These problems have contributed to the collapse or poor implementation of many community-based development programmes, thereby limiting the capacity of local governments to fulfill their

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constitutional responsibilities of providing essential infrastructure and social services to the people. Furthermore, increasing population growth, rising poverty levels, unemployment, and infrastructural decay have intensified pressure on local governments, including Otukpo Local Government Area, to deliver meaningful socio-economic development. However, administrative inefficiency, political interference, poor planning, and inadequate monitoring and evaluation mechanisms continue to undermine development efforts at the grassroots level. Although several studies have examined local government administration and development in Nigeria, limited empirical attention has been given to understanding how effective local government administration can promote sustainable socio-economic development in Otukpo Local Government Area. This gap in the literature necessitates further investigation into the role of local government administration in socio-economic development, the challenges affecting its performance, and the strategies that could enhance effective service delivery and sustainable grassroots development in the study area.

Research Questions

1. What is the problem affecting local government administration and socio-economic development in Otukpo Local Government Area?
2. What is the possible solution to the problems affecting local government administration and socio-economic development in Otukpo Local Government Area?

Objectives of the Study

1. To examine the problems affecting local government administration and socio-economic development in Otukpo Local Government Area.
2. To identify possible solutions to the problems affecting local government administration and socio-economic development in Otukpo Local Government Area.

Research Hypotheses

Ho_1: There is no significant relationship between local government administration and socio-economic development in Otukpo Local Government Area.

Ho_2: There is no significant relationship between the identified solutions and the improvement of local government administration and socio-economic development in Otukpo Local Government Area.

Research Methodology

The study adopted a survey research design, focusing on the staff of the local government council in Otukpo Local Government Area. The population comprised 150 staff members of the council, from which a sample of 109 respondents was selected using a simple random sampling technique. The study was guided by three research questions and three corresponding hypotheses, all tested at the 0.05 level of significance. Data were collected using a structured questionnaire, which was subjected to face validation to ensure its appropriateness and clarity. The instrument yielded a reliability coefficient of 0.68, indicating an acceptable level of internal consistency. The study covered the period from 2025 to 2026. Descriptive statistical tools such as frequency counts and percentages were used to answer the research questions, while the hypotheses were tested using the Pearson Product Moment Correlation Coefficient. The statistical analysis was carried out to determine the relationship between local government administration and socio-economic development in the study area. All were computed using statistical package for social sciences (SPSS).20.0.1. The study therefore specifies the model as follows:

Presentation of Results

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Research question one:

1. What is the problems affecting local government administration and socio- Economic development of Otukpo Local Government Area?

Table 1: Mean rating on the problems affecting local government administration and socio-economic development of Otukpo.

Items	N	Frequency	Mean	SD	Remarks
Inadequate finance	109	49(41.5%)	3.6	1.7	Agreed
excessive interference and control by the central government	109	38(34.2%)	3.5	1.5	Agreed
lack of political will and honesty	109	20(18.6%)	3.1	1.0	Agreed
Lack of integrity and unlawful appropriation of public funds,	109	10(9.2%)	3.2	1.3	Agreed
Lack of accountability and Corruption leaders	109	19 (10.5%)	3.2	1.7	Agreed
Lack of resources and manpower skilled to facilitate a high rate of service delivery	109	6(2.4%)	3.5	1.4	Agreed
Ground mean			3.7		

Field survey, 2026

The aim of Table 1 was to ascertain the problems of local government administration and socio-economic development in Otukpo Local Government. The results show that a majority of respondents, 49 (41.5%), identified inadequate finance as the major constraint. This was followed by 38 (34.2%) respondents who pointed to excessive interference and control by the central government. Additionally, 10 (9.2%) respondents identified lack of integrity and misappropriation of public funds, while 19 (10.5%) attributed the problem to lack of accountability and corruption among leaders. A minority of 6 (2.4%) respondents indicated inadequate resources and shortage of skilled manpower. The findings reveal that respondents generally agreed that all the listed factors constitute major problems affecting local government administration and socio-economic development in Otukpo Local Government.

Research Question Two:

What is the possible solutions to the problems affecting local government administration and socio-economic development in Otukpo Local Government Area?

Table 2: Mean rating on possible solutions to the problems affecting local government administration and socio-economic development in Otukpo

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Items	N	Frequency	Mean	SD	Remarks
Local government administrators must not be selfish, and should show transparency and responsibility in the exercise of their duties.	109	49(41.5%)	3.6	1.7	Agreed
Local government council officials must show honesty, justice and equity to all stakeholders in the system.	109	38(34.2%)	3.5	1.5	Agreed
There is need for the federal allocation to be increased and has to go straight to the local government account to avoid interference by the state government	109	22(18.6%)	3.3	1.0	Agreed
Local governments should play pro-active roles in engaging the services of agricultural extension officers and agents in teaching and dispersing modern farming methods to the farmers.	109	20(10.2%)	3.2	1.3	Agreed
Local governments should strive to raise and maintain revenue that would enable her deliver projects and services that guarantee quality living to the grassroots.	109	19 (8.5%)	3.2	1.7	Agreed
The council should use direct labour in executing of projects rather than the use of contractors, money paid to contractors can be channeled into other developmental projects in the area	109	6(2.4%)	3.5	1.4	Agreed

The aim of Table 2 was to identify the possible solutions to the problems affecting local government administration and socio-economic development in Otukpo Local Government Area. The findings indicate that 49 (41.5%) respondents strongly agreed that local government administrators should demonstrate transparency, responsibility, and selflessness in the discharge of their duties. Similarly, 38 (34.2%) agreed that officials must uphold honesty, justice, and equity in dealing with stakeholders. Furthermore, 22 (18.6%) respondents strongly agreed on the need to increase federal allocations and ensure direct disbursement to local governments to minimize state interference. Also, 20 (10.2%) agreed that local governments should adopt proactive measures by engaging agricultural extension officers to promote modern farming techniques. In addition, 19 (8.5%) strongly agreed that local governments should improve internally generated revenue to enhance service delivery, while

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6 (2.4%) agreed that projects should be executed through direct labour to reduce costs and redirect funds to other developmental needs. The results show that respondents accepted all the identified variables as viable solutions, as each item recorded a mean score above the decision benchmark of 3.0. This implies a general consensus that these strategies can effectively address the challenges of local government administration and promote socio-economic development in Otukpo Local Government Area.

Hypotheses One:

H_{01}: There is no significant relationship between local government administration and socio-economic development in Otukpo Local Government Area

Table 3: Pearson-product moment correlation analysis of the problems of local government administration and socio-economic development in Otukpo.

Variables	∑X ∑Y	∑X² ∑Y²	∑XY	Df	r-cal	r-crit	M(x)	Decision p<.05
Pearson-product moment correlation analysis test.	948	12600	16156	212	0.256	0.195	2.62	*S
Number of valid cases development.	1237	22465						

significant at P < .05 alpha level; N = 109

Using the Pearson Product–Moment Correlation Coefficient, the result in Table 6 shows that the calculated r-value (0.256) is greater than the critical value (0.195) at the 0.05 level with 212 degrees of freedom. Therefore, the null hypothesis is rejected and the alternative hypothesis is accepted. This indicates that there is a significant relationship between local government administration and socio-economic development in Otukpo Local Government Area**.**

Hypothesis Two:

H_{02}: There is no significant relationship between the identified solutions and the improvement of local government administration and socio-economic development in Otukpo Local Government Area

Table 4: Pearson-product moment correlation analysis of solution to the problems of local government administration and socio-economic development in Otukpo Local Government Area.

Variables	∑X ∑Y	∑X² ∑Y²	∑XY	Df	r-cal	r-crit	M(x)	Decision p<.05
Pearson-product moment correlation analysis test.	933	12017	15652	224	0.065	0.195	2.62	*S
Number of valid cases development.	1252	22645						

S = significant at P < .05 alpha level; N = 109

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The result in Table 7 shows that the calculated r-value (0.065) is less than the critical value (0.195) at the 0.05 level with 224 degrees of freedom, indicating no statistically significant relationship. Therefore, the null hypothesis is upheld and the alternative hypothesis is rejected. This implies that there is a significant relationship between the solutions and the improvement of local government administration and socio-economic development in Otukpo Local Government Area.

Discussion of Findings

The test of the first hypothesis one revealed that there is no significant relationship between local government administration and socio-economic development in Otukpo Local Government Area. The Pearson Product Moment Correlation analysis produced a calculated r-value of 0.256, which is greater than the critical r-value of 0.195 at the 0.05 level of significance with 212 degrees of freedom. Since the p-value is less than 0.05, the null hypothesis was rejected. This finding indicates that there is a significant relationship between local government administration and socio-economic development in Otukpo Local Government Area**.** This result is consistent with the findings of Olonta and Azubike (2019). The findings revealed that there are significant problems affecting local government administration, which, in turn, negatively influence socio-economic development. It was further established that weaknesses in administrative structures, poor funding, and the ineffective implementation of policies contribute to the underperformance of local governments. The study also showed that although possible solutions exist to address these challenges, they have not been effectively implemented to yield meaningful improvements in socio-economic development. The study concluded that the persistence of these administrative problems continues to undermine the capacity of local governments to promote development at the grassroots level. It recommended increased federal allocations to local governments, with direct disbursement to reduce external interference, as well as the abolition of the caretaker committee system to strengthen democratic governance, enhance accountability, and improve the delivery of development projects at the local level.

The second hypothesis tested whether there is a significant relationship between the identified solutions and the improvement of local government administration and socio-economic development in Otukpo Local Government Area. The Pearson Product–Moment Correlation analysis presented in Table 4 revealed that the calculated r-value (r = 0.065) is lower than the critical r-value (r = 0.195) at the 0.05 level of significance with 224 degrees of freedom. This indicates that there is no significant relationship between the identified solutions and the improvement of local government administration and socio-economic development in the study area. Therefore, the null hypothesis was accepted, while the alternative hypothesis was rejected. The study indicates that there is a significant relationship between the solutions and the improvement of local government administration and socio-economic development in Otukpo Local Government Area. The study collaborate with the findings of Denga (2018). The findings further revealed that local government administration plays an important role in promoting socio-economic development in the study area. However, persistent administrative challenges were found to hinder effective development outcomes at the local government level. The study also established that although several solutions to these challenges have been identified, they have not been effectively implemented to achieve meaningful socio-economic development. The study concluded that the continued existence of weak implementation structures limits the effectiveness of policy and administrative

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solutions aimed at enhancing grassroots development. Consequently, the study recommended greater fiscal autonomy for local governments through direct disbursement of federal allocations to minimize external interference. It also recommended the abolition of the caretaker committee system in order to strengthen democratic governance, improve accountability, and enhance the effectiveness of local government administration.

Conclusion

Based on the findings, the study concludes that there is a significant relationship between local government administration and socio-economic development in Otukpo Local Government Area. The study also concludes that there is a significant relationship between the identified solutions and the improvement of local government administration and socio-economic development in the study area.

Recommendations

The study therefore recommends that;

1. There is need for the Otukpo local government area to increase their function capacity of these projects and programmes to be able to cover every area of the state.
2. Local governments should be more people-centered in approach, such that necessary collaboration/partnership with communities in its domain can facilitate the process of rural development.
3. There is need for the federal allocation to be increased and has to go straight to the local government account to avoid interference by the state government and caretakership system should be stopped, by so doing, it will go a long way in having more developmental projects

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Effects of Computer-Designed and Mind Mapping Strategies on Achievement and Interest in Genetics among Secondary School Students in Katsina State, Nigeria

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Abstract

This study investigated the effectiveness of computer-designed process mapping and computer-designed mind mapping on senior secondary school students' achievement in Genetics in Katsina State, Nigeria. A 3 × 2 × 2 quasi-experimental pre-test–post-test factorial design was adopted. The study involved 180 Senior Secondary School II Biology students selected from six public secondary schools through a multistage sampling procedure. Data were collected using the Genetics Achievement Test (GAT) and the Students' Interest Questionnaire (SIQ) and analyzed using Analysis of Covariance (ANCOVA) at the 0.05 level of significance. The results revealed significant main effects of treatment, gender, and students' interest on achievement in Genetics. A significant interaction effect was also found between treatment and students' interest, whereas the interaction effects of treatment and gender, gender and students' interest, and the three-way interaction among treatment, gender, and students' interest were not statistically significant. The findings indicate that computer-designed process mapping and computer-designed mind mapping were more effective than the conventional concept mapping strategy in enhancing students' achievement in Genetics. The study concludes that integrating technology-supported visual mapping strategies into Biology instruction can promote meaningful learning and improve students' achievement in Genetics. The study recommends the adoption of these instructional strategies in secondary school Biology classrooms and the provision of adequate teacher training and digital instructional resources to support their effective implementation.

Keywords: Computer-designed; mind mapping; achievement, interest, Genetics

Introduction

Biology is a fundamental science subject in the Nigerian senior secondary school curriculum because it equips learners with scientific knowledge, practical skills, and problem-solving abilities required for higher education and careers in medicine, pharmacy, agriculture, nursing, biotechnology, and other life sciences. The National Policy on Education (Federal Republic of Nigeria [FRN], 2014) and the Nigerian Educational Research and Development Council (NERDC) Biology Curriculum emphasize the development of scientific literacy, critical thinking, and the application of biological knowledge to solving personal and societal problems. Among the topics taught in Biology, Genetics occupies a strategic position because it provides the scientific basis for understanding heredity, variation, evolution, biotechnology, and modern medical sciences. Consequently, a sound understanding of Genetics is indispensable for students pursuing science-related disciplines. Despite its importance, Genetics remains one of the most challenging topics for secondary school students. The abstract nature of many genetic concepts, the interrelationship among biological processes, and the extensive use of scientific terminologies often make the topic difficult to comprehend. Consequently, students continue to record relatively low achievement in Genetics in both internal and external examinations. Several studies have attributed this challenge to the

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persistent use of teacher-centred instructional approaches that emphasize memorization instead of conceptual understanding, thereby limiting students' active participation and meaningful learning (Ajaja, 2019; Coffey, 2020). This situation has continued to stimulate research into innovative instructional strategies capable of improving students' understanding and achievement in Biology.

One instructional strategy that has received considerable attention in science education is concept mapping. Concept mapping is grounded in Ausubel's Meaningful Learning Theory, which posits that meaningful learning occurs when new knowledge is consciously integrated with learners' existing cognitive structures. Through the graphical representation of concepts and their interrelationships, concept maps enable learners to organize knowledge systematically, visualize conceptual relationships, and promote meaningful learning. Recent meta-analyses have confirmed that concept mapping significantly improves students' academic achievement across science disciplines, including Biology, with moderate to large effect sizes reported across different educational contexts. The increasing integration of digital technologies into classroom instruction has expanded the application of concept mapping through computer-assisted instructional approaches. Computer-designed concept maps provide opportunities for interactive visualization, dynamic organization of concepts, multimedia integration, and learner engagement beyond the limitations of conventional paper-based maps. Two important variants of computer-assisted concept mapping are computer-designed process mapping and computer-designed mind mapping.

Computer-designed process mapping presents concepts in a logical and sequential order, enabling learners to visualize biological processes and causal relationships. In contrast, computer-designed mind mapping organizes concepts around a central idea using branches, colours, symbols, keywords, and images, thereby promoting meaningful association, creativity, and long-term retention of knowledge. Both approaches are consistent with constructivist learning principles, which emphasize active learner engagement and knowledge construction. Recent empirical evidence supports the effectiveness of visual learning strategies in Biology education. For example, a quasi-experimental study on Genetics instruction reported that students taught using mind mapping achieved significantly higher academic performance than those taught using conventional teaching methods, while no significant gender differences were observed in the effectiveness of the strategy. Similarly, a comprehensive meta-analysis involving 55 experimental and quasi-experimental studies concluded that concept mapping consistently improves students' achievement in Biology and other science subjects regardless of instructional settings, suggesting that visual knowledge representation remains one of the most effective evidence-based instructional strategies in science education. Apart from instructional strategies, learner characteristics such as gender and students' interest have also been identified as important variables influencing academic achievement. Gender has remained a major concern in science education because differences in classroom participation, learning experiences, and socio-cultural expectations may influence learning outcomes. Likewise, students' interest plays a significant motivational role by enhancing engagement, persistence, and willingness to participate actively during instruction. Students with high interest generally demonstrate greater commitment to learning activities and achieve better academic outcomes than those with lower interest. However, findings regarding the moderating influence of gender and students' interest on Biology achievement remain inconsistent, indicating the need for further empirical investigation. Although previous studies have established the effectiveness of concept mapping in Biology education, most have focused on conventional concept mapping, with relatively limited attention devoted to computer-designed process mapping and computer-designed mind mapping, particularly

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in the teaching of Genetics. Furthermore, few studies have simultaneously examined the moderating roles of gender and students' interest within a single quasi-experimental framework. In Nigeria, existing studies by Hussaini et al. (2025) demonstrated that spider and flowchart concept mapping strategies significantly improved students' attitude, achievement, and retention in Ecology, while Hussaini et al. (2025) further reported that flowchart concept mapping enhanced students' academic performance and retention in Biology. However, these studies focused on Ecology rather than Genetics and did not investigate computer-designed instructional mapping techniques. This gap provides the justification for the present study, which investigated the effectiveness of computer-designed process mapping and computer-designed mind mapping as instructional strategies for enhancing senior secondary school students' achievement in Genetics while considering the moderating influence of gender and students' interest.

Objectives of the Study

This study has the following objectives to:

1. Find out the main effect of treatment on students' achievement in genetics.
2. Determine the main effect of gender on students' achievement in genetics.
3. Examine the main effect of students' interest on students' achievement in genetics.
4. Investigate the interaction effect of treatment and gender on students' achievement in genetics.
5. Find out the interaction effect of treatment and students' interest on students' achievement in genetics.
6. Determine the interaction effect of gender and students' interest on students' achievement in genetics.
7. Examine the interaction effect of treatment, gender, and students' interest on students' achievement in genetics

Research Hypotheses

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

1. There is no significant main effect of treatment on students' achievement in genetics.
2. There is no significant main effect of gender on students' achievement in genetics.
3. There is no significant main effect of students' interest on students' achievement in genetics.
4. There is no significant interaction effect of treatment and gender on students' achievement in genetics.
5. There is no significant interaction effect of treatment and students' interest on students' achievement in genetics.
6. There is no significant interaction effect of gender and students' interest on students' achievement in genetics.
7. There is no significant interaction effect of treatment, gender, and students' interest on students' achievement in genetics.

Research Methodology

Research Design

The study employed a 3 × 2 × 2 quasi-experimental pre-test–post-test factorial research design. The design comprised three instructional strategies, two gender categories (male and female), and two levels of students' interest (high and low). It was considered appropriate because intact school classes were used, making random assignment of individual students impracticable. The design enabled the investigation of the main effects of instructional strategy, gender, and students' interest, as well as their interaction effects on students' achievement in Genetics. The three instructional strategies consisted of two experimental treatments and one comparison group. Students in Experimental

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Group I (E_1) were taught Genetics using Computer-designed Process Mapping, while those in Experimental Group II (E_2) received instruction through Computer-designed Mind Mapping. The Control Group (C) was taught using the Conventional Concept Mapping Strategy. Before the commencement of the treatment, all participants were administered a pre-test to determine their baseline achievement and establish the equivalence of the groups. Following a twelve-week instructional period, a post-test was administered to determine the effectiveness of the instructional strategies on students' achievement in Genetics.

The design is represented as follows:

Group	Pretest	Treatment	Posttest
E_1	O_1	X_1	O_2
E_2	O_1	X_2	O_2
C	O_1	X_0	O_2

Where: E_1 = Experimental Group I; E_2 = Experimental Group II; C = Control Group; O_1 = Pretest O_2 = Posttest; X_1 = Computer-designed Process Mapping; X_2 = Computer-designed Mind Mapping; X_0 = Conventional Concept Mapping Strategy

Population of the Study

The study population comprised all Senior Secondary School II (SS II) Biology students enrolled in public secondary schools in Katsina State during the 2025/2026 academic session. The population included both male and female students offering Biology. SS II students were considered suitable because they had completed the foundational Biology curriculum at the SS I level and possessed sufficient classroom and laboratory experiences to facilitate meaningful learning of Genetics concepts. Furthermore, Genetics is a major component of the SS II Biology curriculum. The students were generally between 15 and 17 years of age.

Sample and Sampling Technique

A multistage sampling procedure was employed to select the study participants. In the first stage, the twelve Educational Quality Assurance Zones in Katsina State constituted the sampling frame. Three zones were selected using simple random sampling through the balloting method. In the second stage, six co-educational public senior secondary schools offering Biology were purposively selected from the sampled zones. Co-educational schools were selected to facilitate the examination of gender as one of the independent variables in the study while excluding single-sex schools. In the third stage, one intact SS II Biology class was selected from each participating school. Where more than one intact class existed, simple random sampling was used to select the class. Approximately sixty Biology students were drawn from each selected school, resulting in a total sample of 180 students. The six participating schools were randomly assigned to the three instructional conditions, with two schools assigned to each treatment condition as follows: Experimental Group I: Computer-designed Process Mapping; Experimental Group II: Computer-designed Mind Mapping; Control Group: Conventional Concept Mapping Strategy. The use of intact classes minimized disruption to normal school activities while preserving the natural classroom setting.

Instruments for Data Collection

Two instruments were used for data collection: Genetics Achievement Test (GAT) and Students' Interest Questionnaire (SIQ)

Genetics Achievement Test (GAT)

The Genetics Achievement Test was developed to assess students' achievement in Genetics. The instrument consisted of multiple-choice questions adapted from past West African Examinations Council (WAEC) and National Examinations Council (NECO) Biology examination questions covering

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Genetics concepts administered between 2020 and 2025. The items adequately represented the instructional objectives and content covered during the treatment period. Each item had four response options, with only one correct answer. One mark was awarded for each correct response, while incorrect responses attracted zero marks. The total score represented each student's achievement level in Genetics.

Students' Interest Questionnaire (SIQ)

The Students' Interest Questionnaire was developed to measure students' level of interest in Genetics before and after the intervention. The questionnaire consisted of statements measured on a four-point Likert response scale of Strongly Agree (4), Agree (3), Disagree (2), and Strongly Disagree (1). The pre-intervention SIQ scores were used to classify students into high- and low-interest categories, with the mean score as the decision criterion. Students who scored at or above the mean were classified as high-interest, whereas those who scored below the mean were classified as low-interest.

Validity of the Instruments

The Genetics Achievement Test and the Students' Interest Questionnaire were subjected to face and content validation by experts in Biology Education and Educational Measurement and Evaluation. The experts examined the instruments for content coverage, clarity of language, appropriateness of the test items, suitability of the questionnaire statements, and alignment with the objectives of the study. Their observations and recommendations were incorporated before the final versions of the instruments were produced.

Reliability of the Instruments

A pilot study was conducted using forty SS II Biology students from a public secondary school outside the study area who did not participate in the main study. The internal consistency of the Students' Interest Questionnaire was determined using Cronbach's Alpha = .89, while the reliability of the Genetics Achievement Test was established using the Pearson Product Moment Correlation = .86.

Procedure for Data Collection

Approval to conduct the study was obtained from the Katsina State Ministry of Basic and Secondary Education, and the principals of the selected schools. Biology teachers who served as research assistants were trained on the study objectives, treatment packages, lesson implementation, and administration of the research instruments to ensure uniformity in instruction. Before the treatment, the Students' Interest Questionnaire (SIQ) and the Genetics Achievement Test (GAT) were administered as pre-test. The SIQ scores were used to classify students into high-interest and low-interest groups, while the GAT scores provided baseline achievement data. The treatment packages were implemented over a period of twelve weeks. Experimental Group I was taught using the computer-designed process mapping package, Experimental Group II received treatment through the computer-designed mind mapping package, while the Control Group was taught using the conventional concept mapping. All groups studied the same genetics topics using similar lesson objectives, instructional periods, classroom activities, and assessment procedures. At the end of the intervention, the GAT and SIQ were re-administered as post-test. The completed instruments were collected, scored, coded, and prepared for statistical analysis. The distribution of participants according to treatment, gender, and interest is presented in Table 1.

Table 1

Distribution of participants by treatment group, gender, and interest

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Treatment Group	Male (High Interest)	Male (Low Interest)	Female (High Interest)	Female (Low Interest)	Total
Computer-designed Process Mapping	15	15	15	15	60
Computer-designed Mind Mapping	15	15	15	15	60
Conventional Concept Mapping Strategy	15	15	15	15	60
Total	**45**	**45**	**45**	**45**	**180**

Treatment Packages

The treatment packages were Adapted from Hussaini (2025) by the researcher to facilitate the implementation of the intervention. To ensure experimental control, all the packages contained similar instructional objectives, lesson contents, instructional periods, classroom activities, assignments, and evaluation procedures.

Treatment Package I: Computer-designed Process Mapping (Experimental Group I)

The instructional activities for the computer-designed process mapping group were implemented as follows: The teacher introduced the lesson by stating the lesson objectives and reviewing students' previous knowledge related to the topic; The teacher presented the computer-designed process map using a computer screen; The teacher explained the genetics concepts by guiding students through the various stages of the process map and emphasizing the logical relationships among concepts; Students observed the process map, identified the sequence of events, and participated in classroom discussions; Students worked individually and in groups to interpret the process maps and complete activities based on the lesson; Students applied the process maps in solving genetics problems and classroom exercises under the guidance of the teacher; The teacher provided immediate feedback, clarified misconceptions, reinforced key concepts, and summarized the lesson using the process map; Students completed assignments designed to reinforce the concepts learned before the next lesson.

Treatment Package II: Computer-designed Mind Mapping (Experimental Group II)

The instructional activities for the computer-designed mind mapping group were implemented as follows: The teacher introduced the lesson by stating the instructional objectives and reviewing relevant prior knowledge; A computer-designed mind map containing the genetics concept was displayed using a computer screen; The teacher explained the central concept and its related branches, demonstrating how the various concepts were interconnected; Students actively participated by identifying relationships among concepts and contributing ideas during classroom discussions; Students individually and in group constructed and interpreted mind maps using computer-designed templates provided by the teacher; Students completed classroom activities and solved genetics-related problems using the mind maps as instructional guides; The teacher evaluated students' responses, corrected misconceptions, and summarized the lesson using the completed mind map; Students were given follow-up assignments requiring them to organize genetics concepts using mind maps.

Conventional Concept Mapping (Control Group)

Students in the control group were taught the same genetics topics using the conventional concept mapping strategy. The teacher presented concept maps illustrating the relationships among related concepts, guided students through classroom discussions and exercises, provided explanations and feedback, summarized each lesson using the concept maps, and assigned follow-up activities. The

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lesson objectives, content, instructional time, classroom activities, and assessment procedures were similar to those used in the experimental groups.

Procedure for Data Analysis

All the hypotheses were tested using Analysis of Covariance (ANCOVA) at the 0.05 level of significance, with the pre-test achievement scores serving as the covariate to control for initial group differences. The analysis determined the main effects of instructional strategy, gender, and students' interest, as well as the interaction effects among these variables on students' achievement in genetics. Prior to the analysis, the assumptions underlying ANCOVA were examined to ensure the appropriateness of the statistical procedure.

Presentation of Results

Table 2 presents the Analysis of Covariance (ANCOVA) examining the effects of treatment, gender, students' interest, and their interaction effects on students' achievement in Genetics, after controlling for pretest achievement. The result revealed that pretest achievement, which served as the covariate, had a significant effect on students' post-test achievement, $F(1, 167) = 185.579$, $p < .05$. This indicates that students' initial achievement significantly predicted their post-test achievement. Thus, controlling for pre-existing differences in students' achievement through ANCOVA was appropriate.

Table 2

ANCOVA of effect of treatment and moderating variables on students' achievement in genetics

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10,465.720	12	872.143	31.175	.000
Intercept	22,548.340	1	22,548.340	805.989	.000
Pretest (Covariate)	5,191.760	1	5,191.760	185.579	.000
Treatment	2,708.160	2	1,354.080	48.401	.000
Gender	136.360	1	136.360	4.874	.029
Interest	221.480	1	221.480	7.917	.006
Treatment × Gender	131.040	2	65.520	2.342	.100
Treatment × Interest	320.320	2	160.160	5.725	.004
Gender × Interest	24.080	1	24.080	0.861	.356
Treatment × Gender × Interest	63.840	2	31.920	1.141	.322
Error	4,728.000	167	27.976		
Total	748,350.000	180			
Corrected Total	15,193.720	179			

The result further showed a statistically significant main effect of treatment on students' achievement in Genetics, $F(2, 167) = 48.401$, $p < .05$. Therefore, Null Hypothesis One was rejected. This indicates that students exposed to the different instructional treatments differed significantly in their achievement in Genetics. The significant treatment effect suggests that the instructional strategies were not equally effective in improving students' achievement. For Null Hypothesis Two, the result revealed a statistically significant main effect of gender on students' achievement in Genetics, $F(1, 167) = 4.874$, $p = .029 < .05$. Therefore, the null hypothesis was rejected. This finding indicates that male and female students differed significantly in their achievement in Genetics after controlling for pretest achievement. Regarding Null Hypothesis Three, the analysis showed a statistically significant main effect of students' interest on achievement in Genetics, $F(1, 167) = 7.917$, $p = .006 < .05$.

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Therefore, the null hypothesis was rejected. This finding indicates that students' level of interest significantly influenced their achievement in Genetics.

For Null Hypothesis Four, the interaction effect between treatment and gender was not statistically significant, $F(2, 167) = 2.342$, $p = .100 > .05$. Therefore, the null hypothesis was retained. This implies that the effectiveness of the instructional treatments did not differ significantly according to students' gender. In other words, the treatment effect was not significantly dependent on whether students were male or female. The result for Null Hypothesis Five showed a statistically significant interaction effect between treatment and students' interest, $F(2, 167) = 5.725$, $p = .004 < .05$. Therefore, the null hypothesis was rejected. This indicates that the effectiveness of the instructional treatments varied significantly according to students' levels of interest. Thus, students with different levels of interest did not respond to the instructional treatments in the same manner. For Null Hypothesis Six, the interaction effect between gender and students' interest was not statistically significant, $F(1, 167) = 0.861$, $p = .356 > .05$. Therefore, the null hypothesis was retained. This indicates that the combined effect of gender and students' interest did not significantly influence students' achievement in Genetics. Finally, Null Hypothesis Seven examined the three-way interaction among treatment, gender, and students' interest. The result was not statistically significant, $F(2, 167) = 1.141$, $p = .322 > .05$. Therefore, the null hypothesis was retained. This indicates that the effectiveness of the instructional treatments did not significantly differ simultaneously according to students' gender and level of interest. The results demonstrate that treatment, gender, and students' interest each had significant main effects on students' achievement in Genetics after controlling for pretest achievement. Of the interaction effects examined, only the Treatment × Interest interaction was statistically significant. However, the Treatment × Gender, Gender × Interest, and Treatment × Gender × Interest interactions were not statistically significant.

Discussion of Findings

The study revealed a significant main effect of treatment on students' achievement in Genetics. This finding indicates that students exposed to the three instructional conditions differed significantly in their achievement after controlling for pretest achievement. The result suggests that the instructional strategies used in the study were not equally effective in promoting students' achievement in Genetics. However, because the ANCOVA only establishes an overall significant treatment effect, the specific differences among the computer-designed process mapping, computer-designed mind mapping, and conventional concept mapping groups should be determined through appropriate post-hoc or pairwise comparisons. The finding is consistent with Ausubel's Meaningful Learning Theory, which emphasizes the meaningful integration of new knowledge with learners' existing cognitive structures. It also agrees with the meta-analysis by Anastasiou, Wirngo, and Bagos (2024), which reported that concept mapping significantly improves students' achievement in science. Similarly, the finding corroborates Hussaini, Kayode, et al. (2025) and Hussaini, Ado, et al. (2025), who reported positive effects of concept-mapping strategies on students' achievement in Biology. The study also revealed a statistically significant main effect of gender on students' achievement in Genetics. This indicates that male and female students differed significantly in their achievement after controlling for their pretest scores. The finding suggests that gender was associated with differences in students' achievement under the conditions of the present study. This finding is consistent with Ugwoke and Ude (2022), who reported significant gender differences in Biology achievement among students taught using concept mapping. However, the finding differs from studies reporting no significant gender differences when technology-supported instructional strategies were used. These differences across studies may be attributable to variations in

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instructional strategies, subject matter, school context, students' characteristics, and methodological procedures.

Students' interest also had a statistically significant main effect on achievement in Genetics. This finding indicates that students with different levels of interest differed significantly in their achievement after controlling for pretest achievement. The result supports the view that students' interest is an important motivational factor in the learning process because interest can influence learners' engagement, attention, persistence, and willingness to participate in learning activities. The finding agrees with Rachmat et al. (2022), who reported that students' interest influenced the use of effective learning strategies in Biology. It also agrees with Awosika and Okoli (2023), who found that mind mapping enhanced students' interest in Biology learning. The interaction effect between treatment and gender was not statistically significant. This finding indicates that the effectiveness of the instructional treatments did not differ significantly between male and female students. In other words, although gender had a significant main effect on achievement, the instructional treatments did not interact significantly with gender. This suggests that the relative effectiveness of the instructional approaches was generally similar for male and female students. The finding agrees with Ugwoke and Ude (2022), who reported no significant interaction between concept mapping and gender on students' achievement in Biology. This finding further suggests that the instructional approaches may be applicable to both male and female learners without substantial differences in treatment effectiveness. In contrast, the interaction effect between treatment and students' interest was statistically significant.

This finding indicates that the effectiveness of the instructional treatments varied significantly according to students' levels of interest. Thus, the achievement differences associated with the instructional treatments were not the same across the different interest groups. This result highlights the importance of considering students' motivational characteristics when implementing innovative instructional strategies. However, the direction and nature of this interaction should be established through simple-effects analysis or pairwise comparisons of estimated marginal means before concluding whether students with high interest benefited more than those with low interest. The finding is related to Awosika and Okoli (2023), who reported that mind mapping could foster students' interest in Biology learning and thereby support learning outcomes. The interaction effect between gender and students' interest was not statistically significant. This indicates that the combined influence of gender and interest did not significantly affect students' achievement in Genetics beyond their individual main effects. Although gender and interest independently showed significant effects, their interaction was insufficient to produce a statistically significant difference in achievement. This suggests that the relationship between students' interest and achievement was not significantly different for male and female students. The finding aligns with Isaak et al. (2022), who reported that gender and interest may independently influence Biology learning without necessarily producing a significant interaction effect. It also supports Eya et al. (2024), who observed that technology-enhanced Biology instruction could reduce gender-related disparities while maintaining students' interest in learning. Finally, the three-way interaction among treatment, gender, and students' interest was not statistically significant. This indicates that the combined interaction of instructional treatment, gender, and students' interest did not produce a statistically significant additional effect on students' achievement in Genetics. The result suggests that there was insufficient evidence to conclude that the effectiveness of the instructional treatments simultaneously varied according to both gender and interest. This finding implies that the treatment

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× interest interaction observed in the study was not further conditioned by gender. The finding is consistent with studies reporting that technology-enhanced instructional approaches can improve learning outcomes across different categories of learners without necessarily producing significant higher-order interactions among instructional and learner variables (Balogun et al., 2026; Eya et al., 2024).

Conclusion

The study concludes that the instructional treatments significantly influenced senior secondary school students' achievement in Genetics after controlling for pretest achievement. Gender and students' interest also had significant main effects on students' achievement. Furthermore, a significant interaction was found between treatment and students' interest, indicating that the effectiveness of the instructional treatments varied according to students' levels of interest. However, the interactions between treatment and gender, gender and students' interest, and the three-way interaction among treatment, gender, and students' interest were not statistically significant. Therefore, the findings demonstrate the potential of computer-designed visual instructional strategies, particularly process mapping and mind mapping, as approaches for improving the teaching and learning of Genetics. Nevertheless, claims about which specific treatment was superior should be based on the post-hoc or pairwise comparison results rather than the overall significant treatment effect alone. The findings also suggest that teachers should consider students' interest when implementing innovative instructional strategies, as students' interest may influence how effectively they respond to different instructional approaches.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Biology teachers should adopt computer-designed process mapping and computer-designed mind mapping as instructional strategies for teaching genetics, as they significantly enhance students' achievement compared with the conventional concept mapping strategy.
2. Curriculum developers, the Nigerian Educational Research and Development Council (NERDC), and other relevant educational agencies should integrate computer-assisted visual instructional strategies into the senior secondary Biology curriculum to promote meaningful learning of abstract genetics concepts.
3. School administrators and educational stakeholders should provide Biology teachers with adequate ICT facilities, including computers, multimedia projectors, and relevant instructional software, to facilitate the effective implementation of computer-designed instructional strategies in Biology classrooms.
4. Teacher education institutions and professional development providers should organize regular workshops, seminars, and in-service training programmes to equip Biology teachers with the knowledge and skills required to develop and effectively use computer-designed process maps and mind maps during instruction.
5. Since students' interest significantly influenced achievement in Genetics, Biology teachers should employ learner-centred and technology-enhanced instructional approaches that stimulate and sustain students' interest in Biology learning.
6. The significant effect of gender suggests that Biology teachers should adopt inclusive instructional practices that encourage active participation and equal learning opportunities for both male and female students during classroom instruction.

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7. Future researchers should replicate this study in other Biology topics, science subjects, educational levels, and geographical locations using different moderating variables to further validate and generalize the findings of the study.

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Effect of Intelligent-Tutoring Strategy on Attitude Towards Biology Learning among Secondary School Students in Suleja, Niger State, Nigeria

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Abstract

This paper looked at differences in attitude towards biology of male and female secondary school students who were taught with the use of intelligent tutoring instructional strategy in Suleja, Niger State, Nigeria. The paper used a pretest-posttest quasi-experimental design with 60 students in the experimental group. Out of the 60 students, 34 were males and 26 were females. The data was collected by means of an attitude questionnaire and analyzed using mean, standard deviation and independent-samples t-test at a level of significance of 0.05. The results showed that male students scored 9.78 and 18.29 mean attitudes in pretest and posttest respectively, compared to the females' 9.51 and 18.01 mean attitudes respectively. The corresponding mean gain scores were 8.51 for male students and 8.50 for female students, suggesting that both genders made considerable and nearly equal gains in their attitude towards Biology. The inferential results revealed that there was no significant difference in pre-test attitude scores of male and female students, t(58) = 0.96, p = .341; post-test attitude scores, t(58) = 0.99, p = .325; or mean gain scores, t(58) = 0.04, p = .968. Therefore, all the three null hypotheses were not rejected. This study shows that Intelligent-Tutoring Instructional Strategy develops positive attitude towards Biology in male and female students without making a statistically significant difference based on the gender of students.

Keywords: Gender, Biology, Attitude and Intelligent Tutoring Strategy

Introduction

Biology is an important science subject at the secondary level, as it gives the learner information on the workings of living things, human health, environmental sustainability, agricultural practices, and biotechnology among other disciplines necessary for personal and national development. Nonetheless, the success in Biology instruction requires not just the cognitive development of the learner but also attitudes, interests, motivation, and desire of the learner to learn Biology. In Nigeria, the secondary school system, the issue of unfavorable attitudes of the learner towards science subjects has consistently aroused interest in novel ways of teaching Biology. New evidence suggests that the adoption of instructional methods has a considerable effect on students' attitudes towards Biology, such that Ugwu et al. (2024) revealed significant differences in the attitude of students exposed to different instructional methods, as well as gender interaction, and Ejigbo et al. (2024) also revealed the improvement in students' attitudes towards Biology through collaborative teaching methods that are innovative. As a result of AI's increasing application in the education sector, a new instructional strategy named the Intelligent Tutoring Instructional Strategy (ITIS) has emerged as an adaptive method able to give individualized explanations, feedback, and practice. New studies from Nigeria have also emphasized the significance of intelligent tutoring systems and AI-enabled learning especially in relation to learners' perception, usefulness, and behavioral intention towards AI-based learning systems. Nonetheless, most of the available evidence from Nigeria has been centered on academic performance, technology adoption or behavioral intention, but not on the affective consequences that can result from biology instruction. This is why the study of students' attitude

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becomes critical especially since a particular instructional approach could lead to high academic performance without necessarily eliciting similar attitudes among males and females.

This study is primarily based on the Constructivist Learning Theory that suggests that learning takes place actively through meaningful experiences and interactions between the learners and the learning environment, and this theory is especially applicable in relation to intelligent tutors as it enables personalized scaffolding for active knowledge construction. The Technology Acceptance Model developed by Davis (1989) offers an additional perspective by providing an explanation of the influence of perceived usefulness and ease of use on attitudes toward technology-based learning, with modern research still exploring the perspectives related to technology acceptance in the context of AI-based educational contexts (Boor et al., 2026; Zhang et al., 2026). Although there has been increasing amount of scholarly attention paid to innovative approaches in Biology education, a substantial gap remains in relation to the examination of gender differences in the attitudes of learners toward Biology after intelligent-tutoring instruction in Nigerian secondary schools. Gender disparity in attitudes towards Biology and effectiveness of creative teaching techniques have been explored by Nigerian researchers (Ugwu et al., 2024; Ejigbo et al., 2024). Intelligent tutoring has been assessed by Aghayere and Awoyeye (2026) among secondary school students in Suleja, but with an emphasis on the effects on learning outcomes, not gender-related attitudes towards Biology. As a result, no reliable information is available about whether attitudes towards Biology formed by boys and girls in an intelligent tutoring environment are the same. This gap creates a practical challenge for Biology teachers, curriculum developers, and policy makers who need evidence that will help to understand if new methods of instruction can promote positive attitudes among genders. The present study therefore focuses specifically on gender differences in attitude toward Biology among secondary school students exposed to Intelligent-Tutoring Instructional Strategy in Suleja, Niger State, Nigeria, thereby extending existing scholarship from achievement and technology adoption to the affective dimension of Biology learning. By addressing this gap, the study is expected to contribute empirical evidence for improving technology-supported Biology instruction, strengthening learner-

Review of Literature

The attitude towards Biology by students constitutes an essential affective component in science education since it entails the interest, self-confidence, usefulness, enjoyment, and willingness of learners to participate in activities associated with Biology. The attitude can enhance the motivation and participation of learners, while a negative attitude can demotivate learners from engaging actively and developing future dispositions for science education. In the case of Nigeria's secondary schools, the manner in which lessons are taught in class constitutes another crucial factor in shaping the learners' attitudes, especially since traditional teaching-centered methods are continuously being criticized and replaced by learner-centered and technology-based methods. Ugwu et al. (2024) noted that the method of instruction played a vital role in the attitudes of learners towards Biology. Likewise, Ejigbo et al. (2024) demonstrated that a novel collaborative instructional approach had a positive effect on the attitude of students towards Biology, showing the ability of alternative approaches to have an impact on affective learning. The development of artificial intelligence technology provides additional opportunities to personalize instruction through the use of systems that adapt content and give immediate feedback, adjusting to the learner's individual needs (Akhter et al., 2026). Intelligent tutoring systems, in particular, can help to create an interactive learning environment where students will get individual explanations and practice under the continuous guidance of instructors, rather than rely solely on explanations given by the instructor during the whole-class instruction (Boor et al., 2026). Contemporary literature also shows that students' views

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about the usefulness, accessibility, and ease of interaction may play an important role in accepting intelligent learning environments (Zhang et al., 2026). All the above-mentioned developments show that intelligent tutoring can become a good solution for promoting students' affective engagement with Biology; however, it has to be investigated in relation to a particular context of education rather than being transferred to another educational setting.

The theoretical basis of the current research study is largely grounded on the Constructivist Learning Theory, which views learning as an active process where learners construct their understanding of concepts by interacting with experiences, materials, feedback, and their environment. It is fitting that intelligent tutoring systems be used in this respect, as they can help learners to build up scaffolds, receive feedback individually and interact with Biology content at a pace appropriate for them. The Technology Acceptance Model (TAM) can complement the previous theory, according to which perceived usefulness and perceived ease of use affect people's attitudes and behavior in technology-based settings (Davis, 1989); this point still holds true in relation to contemporary artificial intelligence-based education (Boor et al., 2026). However, empirically, there has been much uncertainty with regard to the issue of gender differences between males and females in terms of their reactions to technology-enhanced Biology lessons. In the case of Nigeria, previous studies have generally focused on innovative instructional strategies vis-à-vis the effect of biology achievement, attitudes or technology adoption while considerably less research focus has been paid to gender disparity in attitude as a result of intelligent-tutoring instructional strategy. For example, Aghayere and Awoyeye (2026) conducted an Intelligent-Tutoring Instructional Strategy study involving secondary school students in Suleja, but their research concentrated on achievement as opposed to gender disparity in attitude. Therefore, there is a need to find out whether male and female secondary school students exposed to intelligent-tutoring instruction exhibit disparate attitudes towards Biology. Hence, the current study attempts to bridge the gap by examining the pre-test and post-test attitudes, and the mean gain scores of male and female secondary school students exposed to Intelligent-Tutoring Instructional Strategy in Suleja, Niger State.

Research Objective

The primary objective of this study is to investigate gender differences in attitude towards Biology among secondary school students who have been taught using Intelligent-Tutoring Instructional Strategy in Suleja, Niger State, Nigeria. In particular, the study intends to:

1. ascertain the mean attitude scores of male and female secondary school students towards Biology prior to the Intelligent-Tutoring Instructional Strategy;
2. ascertain the mean attitude scores of male and female secondary school students towards Biology post-exposure to the Intelligent-Tutoring Instructional Strategy; and
3. ascertain whether there exists a statistically significant difference between the attitude scores of male and female secondary school students towards Biology post exposure to the Intelligent-Tutoring Instructional Strategy.

Research Questions

The following research questions guided the study:

1. What are the mean attitude scores of male and female secondary school students toward Biology before exposure to Intelligent-Tutoring Instructional Strategy?
2. What are the mean attitude scores of male and female secondary school students toward Biology after exposure to the Intelligent-Tutoring Instructional Strategy?
3. What difference exists between the attitude scores of male and female secondary school students toward Biology after exposure to the Intelligent-Tutoring Instructional Strategy?

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Null Hypotheses

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

H_{01}: There is no significant difference between the mean attitude scores of male and female secondary school students toward Biology before exposure to Intelligent-Tutoring Instructional Strategy.

H_{02}: There is no significant difference between the mean attitude scores of male and female secondary school students toward Biology after exposure to Intelligent-Tutoring Instructional Strategy.

H_{03}: There is no significant difference between the mean attitude scores of male and female secondary school students toward Biology following exposure to Intelligent-Tutoring Instructional Strategy.

Research Methodology

The study adopted a quasi-experimental research design, specifically a pre-test–post-test design, to examine gender differences in attitude toward Biology among secondary school students exposed to Intelligent-Tutoring Instructional Strategy in Suleja, Niger State, Nigeria. The population comprised 2,866 SS II students offering Biology, from which 120 students were selected from two purposively selected co-educational secondary schools. The sample consisted of 68 male and 52 female students, while the experimental group used for the intervention and gender comparison comprised 60 students, including 34 males and 26 females. Data were collected using a researcher-developed 30-item Biology Attitude Scale (BAS), which was validated by four experienced Biology teachers with WAEC marking experience. The instrument was administered as a pre-test before the intervention and as a post-test after the intervention to determine students' attitudes toward Biology. The Intelligent-Tutoring Instructional Strategy was implemented for five weeks, with approximately 80-minute instructional sessions, during which students received Biology instruction through the technology-supported learning approach. The reliability of the Biology Attitude Scale was established using Cronbach's alpha, which yielded a coefficient of 0.79, indicating satisfactory internal consistency for the study. The researcher coordinated the administration and retrieval of the instruments, while participants' responses were treated confidentially and used strictly for research purposes. Data obtained from the pre-test and post-test were coded according to students' gender and analysed using mean and standard deviation to answer the research questions. Mean gain scores were also considered to describe changes in students' attitudes following exposure to the Intelligent-Tutoring Instructional Strategy. The null hypotheses were tested at the 0.05 level of significance using an independent-samples t-test to determine whether significant differences existed between the attitude scores of male and female students. The statistical analysis and interpretation were restricted to the differences supported by the available data, particularly the distinction between post-test attitude differences and actual pre-test-to-post-test attitudinal gains.

Presentation of Results

Research Question 1: What are the mean attitude scores of male and female secondary school students toward Biology before exposure to Intelligent-Tutoring Instructional Strategy?

Table 1: Mean and Standard Deviation of Male and Female Students' Pre-test Attitude Scores toward Biology

Gender	Number of Students	Mean	Standard Deviation
Male	34	9.78	1.06
Female	26	9.51	1.11
Mean Difference	—	**0.27**	—

Source: Field Survey, 2025.

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From Table 1 above, it is observed that male respondents had a pre-test mean attitude score of 9.78, with a standard deviation of 1.06, whereas females had a mean attitude score of 9.51, with a standard deviation of 1.11. It can thus be said that the mean difference of 0.27 shows that male students had a slightly higher mean attitude score than female students towards Biology prior to the use of the Intelligent-Tutoring Instructional Strategy.

Research Question 2: What are the mean attitude scores of male and female secondary school students toward Biology after exposure to Intelligent-Tutoring Instructional Strategy?

Table 2

Mean and Standard Deviation of Male and Female Students' Post-test Attitude Scores toward Biology

Gender	Number of Students	Mean	Standard Deviation
Male	34	18.29	1.06
Female	26	18.01	1.11
Mean Difference	—	**0.28**	—

Source: Field Survey, 2025.

According to Table 2, the post-test attitude score of the male students had a mean of 18.29 and a standard deviation of 1.06, while for the female students, the mean was 18.01 with a standard deviation of 1.11. The difference in the means is 0.28, which shows that the post-test attitude score of the male students was slightly higher than that of the female students when exposed to the Intelligent-Tutoring Instructional Strategy.

Research Question 3: What difference exists between the attitude scores of male and female secondary school students toward Biology after exposure to Intelligent-Tutoring Instructional Strategy?

Table 3: ***Mean Gain Scores of Male and Female Students' Attitude toward Biology following Exposure to Intelligent-Tutoring Instructional Strategy***

Gender	Number of Students	Pre-test Mean	Post-test Mean	Mean Gain
Male	34	9.78	18.29	8.51
Female	26	9.51	18.01	8.50
Mean Gain Difference	—	—	—	**0.01**

Source: Field Survey, 2025.

According to Table 3, the male group had a mean gain score of 8.51, whereas the female group had a mean gain score of 8.50. Thus, the difference between the mean gain scores for the two groups was 0.01, meaning that there was virtually no difference in change in attitude towards Biology between the two genders after the implementation of the Intelligent-Tutoring Instructional Strategy. Even though the males had a slightly higher mean gain than the females, the difference was very minimal at a descriptive level. It means that the Intelligent-Tutoring Instructional Strategy brought about a similar change in attitude towards Biology for the two genders.

H_{01}: There is no significant difference between the mean attitude scores of male and female secondary school students toward Biology before exposure to the Intelligent-Tutoring Instructional Strategy.

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Table 4: Independent-Samples t-test of Mean Pre-test Attitude Scores of Male and Female Students toward Biology

Gender	N	$\bar{X}$	SD	df	t-value	Sig. (P)	Decision
Male	34	9.78	1.06	58	0.96	0.341	Not rejected
Female	26	9.51	1.11				

Note: Not significant at P > .05. Source: Field Survey, 2025.

As shown in Table 4, the mean pre-test attitude score for male students was 9.78 with a standard deviation of 1.06 and for female students was 9.51 with a standard deviation of 1.11. The obtained t-value of 0.96 with a degree of freedom of 58 produced a significance probability of 0.341. As P = 0.341 is greater than 0.05, the difference observed was statistically insignificant. Thus, hypothesis H_{01} was not rejected. This suggests that there was no significant difference between the mean pre-test attitude scores of male and female students towards Biology prior to the application of Intelligent-Tutoring Instructional Strategy.

H_{02}: There is no significant difference between the mean attitude scores of male and female secondary school students toward Biology after exposure to Intelligent-Tutoring Instructional Strategy.

Table 5: Independent-Samples t-test of Mean Post-test Attitude Scores of Male and Female Students toward Biology after Exposure to Intelligent-Tutoring Instructional Strategy

Gender	N	$\bar{X}$	SD	df	t-value	Sig. (P)	Decision
Male	34	18.29	1.06	58	0.99	0.325	Not rejected
Female	26	18.01	1.11				

Note: Not significant at P > .05. Source: Field Survey, 2025.

From Table 5 above, it is evident that the post-test mean attitude score of male students is 18.29 with a standard deviation of 1.06, while the mean score for females is 18.01 with a standard deviation of 1.11. The t-score computed was 0.99 at 58 degrees of freedom, while the level of significance was 0.325. Because P = 0.325 > 0.05, there was no significant difference. H_{02} was thus not rejected. It can be said that there was no significant difference between the mean post-test attitude scores of male and female students towards Biology.

H_{03}: There is no significant difference between the mean attitude gain scores of male and female secondary school students toward Biology following exposure to Intelligent-Tutoring Instructional Strategy.

Table 6: Independent-Samples t-test of Mean Attitude Gain Scores of Male and Female Students toward Biology

Gender	N	$\bar{X}$	SD	df	t-value	Sig. (P)	Decision
Male	34	8.51	1.03	58	0.04	0.968	Not rejected
Female	26	8.50	1.08				

Note: Not significant at P > .05. Source: Field Survey, 2025.

From Table 6, it is clear that the average attitude gain score for the male students was 8.51, with a standard deviation of 1.03, whereas that of the female students was 8.50, with a standard deviation of 1.08. The difference between the two average attitude gain scores was only 0.01. The t-value obtained after calculation from the data set was 0.04, with 58 degrees of freedom. As a result of this, the probability of significance was 0.968. Since P = 0.968 > 0.05, the difference was not statistically

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significant. Thus, H_{03} was not rejected, and there was no difference between the two average attitude gain scores.

Discussion of Results

One of the most important results of the study was the finding that boys scored higher on average than girls (9.78 versus 9.51); however, an independent-samples t-test failed to prove the statistical significance of the difference between the means ($t(58) = 0.96$, $p = .341$). Thus, it can be argued that the attitudes of boys and girls towards Biology prior to the intervention were similar. The result is partially supported by the reviewed literature, especially the information that the students' attitude to Biology depends not on their gender but on the nature of the instruction process. It does not support the findings of Ugwu et al. (2024), however, who found gender-related attitudes toward Biology after the intervention. This difference can be explained by different teaching contexts, different learner characteristics, different intervention plans, or even different ways of measuring the attitude itself. This result, therefore, offers a contextual qualifier to the findings by Ugwu et al. (2024) concerning the differences observed between male and female learners regarding the attitudes towards Biology. In the light of Constructivist Learning Theory, the similarity of attitudes makes perfect sense because both groups were taught in the same environment where interaction with the learning material would be similar enough to offer a basis for future learning. The second finding which is a little bit more pronounced in nature is the significant improvement of attitude towards Biology for both male and female students due to exposure to the Intelligent-Tutoring Instructional Strategy. For the male group, the mean attitude changed from 9.78 to 18.29 from the pre-test to the post-test. On the other hand, for the female group, the mean attitude shifted from 9.51 to 18.01. This results in a gain of 8.51 and 8.50 for the male and female groups respectively. However, there is no significant difference in post-test scores between both groups, $t(58)=0.99$, $p=.325$. This result is supported by the research conducted by Ejigbo et al. (2024) which showed that an innovative instructional strategy can positively affect the attitude of students towards Biology, and also the general idea put forth by Akhter et al. (2026) and Boor et al. (2026). The similar gain scores indicate that the approach did not favor any particular gender. Therefore, the findings are able to contribute to the literature on technology-based learning approaches in terms of how they influence affective factors in intelligent tutoring for Biology. The finding also makes sense in the light of Constructivist Learning Theory, as the approach gives the learners an opportunity to actively engage with the material and learn through feedback. In addition, the finding could also be explained through the Technology Acceptance Model. According to Zhang et al. (2026), an environment which is perceived to be useful and easy to interact with will lead to the development of positive attitudes towards it, regardless of gender.

The third result, which is essentially the main result of the current study, was that there was no statistically significant gender difference in attitude gain after exposure to the Intelligent-Tutoring Instructional Strategy, where male students gained an average of 8.51 compared to female students' gain of 8.50; the insignificant difference of 0.01 was not statistically significant, $t(58) = 0.04$, $p = .968$. The above result shows that the intelligent-tutoring setting was associated with gender-comparable affective results, and hence debunks the assumption that male students always react better to technology-based Biology teaching than female students. In this regard, the result contrasts with that of Ugwu et al. (2024), which showed gender differences, but it conforms to the general implication by Boor et al. (2026). It further builds on Ejigbo et al. (2024) in the sense that the positivity of attitudes generated through innovative teaching could happen even without a statistically significant gender difference. The importance of this finding in the Nigerian context is

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that, according to the literature review, there have not been many studies that have considered the issue of gender differences in relation to attitude formation after intelligent tutor instruction. The current study thus seeks to fill the gap in terms of the empirical findings and the context. The study shows that the male and female students in Suleja can benefit equally in terms of their attitudes through the Intelligent-Tutoring Instructional Strategy.

Conclusion

The results of the research indicate that the use of the Intelligent-Tutoring Instructional Strategy increased the attitudes of the students towards the study of Biology in both males and females of the secondary schools in Suleja, Niger State. While it is true that there was a slightly higher mean attitude score recorded in males as compared to females both at pre-test and post-test levels, there was no statistically significant difference between them. This is evident from the equal gain scores in the two groups.

Recommendations

In light of the results above, the following recommendations have been made:

1. Biology teachers ought to employ the Intelligent-Tutoring Instructional Strategy in their classroom teaching in order to improve students' attitudes towards biology.
2. There should be provision for enough ICT equipment and facilities as well as digital content to facilitate the implementation of intelligent-tutoring instruction.
3. Biology teachers should regularly be trained on how best to use intelligent-tutoring instruction technologies.
4. School administrators should advocate gender inclusiveness in technology-based instruction due to the fact that the method produced similar attitudinal results between male and female students.
5. Educational policymakers should encourage responsible use of artificial intelligence in secondary school Biology curriculum and teachers' professional development programs.
6. Further studies need to be done in various schools and regions in order to determine the consistency and validity of these results.

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Assessment of Pedagogical and Content Competence on Physics Curriculum Implementation among Secondary School Teachers in Imo State, Nigeria

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Abstract

This study examined Physics teachers' pedagogical and content competence and determined whether these competences differed according to years of teaching experience and academic qualification. A descriptive survey research design was adopted. The study involved 56 Physics teachers selected using convenience sampling. Data were collected using a researcher-developed instrument titled the Physics Teachers' Competence Questionnaire (PTCQ). The instrument had Cronbach's alpha reliability coefficients of 0.89 for the Pedagogical Competence Scale, 0.92 for the Content Competence Scale, and 0.94 for the entire instrument. The data were analyzed using frequencies, percentages, means, standard deviations, and one-way analysis of variance (ANOVA) at the 0.05 level of significance. The findings showed that Physics teachers reported a high level of pedagogical competence (weighted mean = 3.47) and content competence (weighted mean = 3.40). There was no significant difference in pedagogical competence based on years of teaching experience, $F_{(3, 52)} = 1.416$, $p = .249$, or in content competence based on years of teaching experience, $F_{(3, 52)} = 0.284$, $p = .837$. Similarly, academic qualification did not significantly influence teachers' overall competence, $F_{(4, 51)} = 2.286$, $p = .073$. The study concludes that the teachers reported a high-level pedagogical and content competence in implementing the Physics curriculum, while years of teaching experience and academic qualification did not significantly differentiate their reported competence. Continuous professional development is recommended to strengthen teachers' competence, particularly in ICT integration and the explanation of abstract Physics concepts and quantitative problem-solving.

Keywords: Pedagogical competence; content competence; physics teachers; physics curriculum

Introduction

The quality of Physics education is intricately connected to the competence of teachers who are responsible for translating curriculum expectations into meaningful classroom experiences. Physics is a conceptually and mathematically demanding subject. It requires teachers not only to possess adequate knowledge of Physics content but also to understand how that content can be represented, explained, demonstrated, and assessed in a way that facilitate students' learning. Effective implementation of the Physics curriculum requires an appropriate combination of content competence and pedagogical competence. Teachers' competence encompasses the knowledge and skills that enable teachers to understand subject matter, select appropriate instructional approaches, respond to students' learning difficulties, and connect abstract concepts with meaningful learning experiences. Content competence is particularly important in Physics because teachers frequently deal with concepts that require conceptual understanding, mathematical reasoning, problem-solving skills, and the ability to distinguish scientifically accepted explanations from students' alternative conceptions. Studies have shown that teachers' knowledge of Physics content is a vital component of their professional knowledge. For example, Etkina et al. (2018) demonstrated the importance of assessing teachers' content knowledge specifically in relation to

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teaching Physics, rather than treating subject knowledge as independent of instructional demands. Similarly, Ramma et al. (2024) highlighted continuing concerns about Physics teachers' content knowledge, particularly in relation to the teaching of specific concepts such as upthrust. Teachers' content knowledge also influences how they notice and interpret events during classroom instruction. Chan and Van Driel (2026), in comparing expert and novice teachers, showed that content knowledge and pedagogical content knowledge play important roles in teacher noticing. These findings suggest that knowledge of Physics content is not merely a prerequisite for answering Physics questions but is also important for making appropriate instructional decisions.

Pedagogical competence is equally essential because knowing Physics does not automatically translate into the ability to teach Physics effectively. Pedagogical content knowledge (PCK) refers to the transformation of subject-matter knowledge into forms that are accessible and meaningful to learners. Research has indicated that more and less experienced teachers may activate different forms of knowledge when interpreting and analyzing classroom instruction (Krepf et al., 2018). Likewise, Ibrahim et al. (2014) found differences in pedagogical content knowledge between expert and novice lecturers, while Jang et al. (2013) examined the development of PCK among novice and experienced university Physics instructors. Karal and Alev (2016) further showed that prospective Physics teachers' PCK develops during their initial teacher preparation. These studies collectively indicate that effective Physics teaching involves more than mastery of disciplinary content; it requires teachers to possess and apply knowledge about how Physics concepts can best be taught to learners. The relationship between teachers' competence and classroom practice has also received considerable attention in Physics education research. Freitas et al. (2004), for instance, found differences in the conceptions and practices of an experienced and an inexperienced Physics teacher while solving Physics problems. Caleon et al. (2018) similarly examined the beliefs and practices of beginning and experienced Physics teachers, demonstrating the relevance of teaching experience to understanding teachers' professional practice. However, the relationship between experience and teachers' competence is not necessarily straightforward. Mirzaei et al. (2020), in comparing experienced and inexperienced Physics teachers' reflective teaching skills, considered differences across levels of reflection, suggesting that teaching experience alone may not fully explain differences in teachers' professional capabilities. Thus, empirical investigation is needed to determine whether differences in teachers' competence are associated with years of teaching experience within educational contexts.

The significance of teachers' competence is further supported by evidence linking teachers' professional knowledge with students' learning outcomes. Gess-Newsome et al. (2019) reported a relationship among teachers' pedagogical content knowledge, classroom practice, and student achievement, while Keller et al. (2017) found that Physics teachers' pedagogical content knowledge and motivation were associated with students' achievement and interest. These findings reinforce the view that teachers' competence is not simply an attribute of teachers themselves but has implications for the quality of classroom instruction and students' educational experiences. In the context of Physics, therefore, examining teachers' competence provides an important basis for understanding the extent to which teachers are prepared to implement the prescribed curriculum effectively. The issue of teachers' competence is particularly relevant in the Nigerian educational context, where concerns about teacher preparation, quality, and continuous professional development have been documented. Omosewo (2009) emphasized the need for the training and retraining of Physics teachers in Nigeria, indicating that professional development remains an

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important consideration in improving Physics teaching. Aina and Olanipekun (2015) similarly drew attention to teacher self-efficacy, pedagogical content knowledge, and out-of-field teaching among Nigerian teachers. Evidence from Nigerian studies has also connected teacher quality and qualification with students' learning outcomes in Physics. Tella and Aduramo (2016) examined teacher quality as a correlate of students' learning outcomes in Physics in Osun State, while Shedrack and Nduudee (2023) investigated teachers' qualifications and secondary school Physics students' academic performance in Rivers State. More recently, Eyenaka et al. (2023) examined the relationship between teachers' quality and the academic performance of Physics students in public secondary schools in Akwa Ibom State. These studies indicate sustained interest in the quality, qualification, and competence of Physics teachers in Nigeria.

Despite this body of research, an important gap remains. Much of the existing literature has focused on dimensions of teacher knowledge, such as PCK, content knowledge, reflective teaching skills, teacher qualification, or teacher quality. Less attention has been given to examining pedagogical and content together in the context of Physics curriculum implementation. Furthermore, existing Nigerian studies have been conducted in different states and have examined teacher quality, qualification, or learning outcomes, but the evidence specifically concerning the pedagogical and content competence of Physics teachers in public senior secondary schools in Imo State remains limited. In addition, although previous studies have compared expert and novice teachers or examined the role of teaching experience, there is a need for context-specific evidence on whether years of teaching experience are associated with differences in Physics teachers' pedagogical and content competence. Another gap concerns academic qualification. Academic qualification is commonly regarded as an indicator of teachers' professional preparation, yet possession of a higher academic qualification does not necessarily guarantee greater competence in curriculum implementation. The existing literature provides evidence concerning teacher qualification and student achievement in different Nigerian contexts (Shedrack & Nduudee, 2023; Tella & Aduramo, 2016), but there is insufficient evidence concerning whether teachers' academic qualifications are associated with differences in their overall competence to implement the Physics curriculum. Determining whether competence varies according to academic qualification is important because such evidence may inform teachers recruitment, professional development, and continuing teacher education. This study therefore addresses this gap by examining the pedagogical and content competence of Physics teachers in the implementation of the Physics curriculum in public senior secondary schools in Imo State.

Research Question

1. What is the level of pedagogical competence of Physics teachers in implementing the Physics curriculum in public senior secondary schools in Imo State?
2. What is the level of content competence of Physics teachers in implementing the Physics curriculum in public senior secondary schools in Imo State?

Null Hypotheses

1. There is no significant difference in the reported pedagogical competence of Physics teachers according to years of teaching experience.
2. There is no significant difference in the reported content competence of Physics teachers according to years of teaching experience.
3. There is no significant difference in the overall competence of Physics teachers according to academic qualification.

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Research Methodology

Research Design

The study adopted a descriptive survey research design. The design was considered appropriate because the study sought to describe Physics teachers reported pedagogical and content competence and to examine whether these reports differed according to years of teaching experience and academic qualification.

Sample and Sampling Technique

The study sample comprised 56 Physics teachers. A convenience sampling technique was used to select the respondents. Physics teachers who were accessible and available to participate in the study were approached and invited to complete the questionnaire. The questionnaire was distributed to eligible Physics teachers through accessible channels, and data collection continued until no additional accessible respondents could be reached. Convenience sampling was used because access to complete sampling frame was unavailable, and participation depended on the accessibility and willingness of eligible teachers to respond. Consequently, the finding should be interpreted cautiously and should not be generalized beyond the participating teachers without further evidence.

Research Instrument

Data were collected using a researcher-developed instrument titled Physics Teachers' Competence Questionnaire (PTCQ). The PTCQ consisted of two sections. Section A obtained demographic information of the respondents, including gender, age, highest academic qualification, years of teaching experience, and school location. Section B measured teachers' competence and was divided into two subscales: Pedagogical Competence Scale (PCS) and Content Competence Scale (CCS). The Pedagogical Competence Scale (PCS) consisted of ten self-report items designed to measure teachers' perceived ability to implement the Physics curriculum. The Content Competence Scale (CCS) also consisted of ten self-report items designed to measure teachers' perceived knowledge and understanding of major areas of the Physics curriculum. The items were structured on a four-point Likert-type scale ranging from Strongly Agree (SA), Agree (A), Disagree (D) to Strongly Disagree (SD). The response options were assigned numerical values of 4, 3, 2, and 1, respectively.

Validation of the Instrument

The Physics Teachers' Competence Questionnaire was subjected to face and content validation by five experts in Physics education, measurement and evaluation, and curriculum studies. The experts evaluated the clarity, relevance, adequacy, appropriateness, and coverage of the items in relation to the study objectives and research questions. Their observations and suggestions were used to modify, clarify, and improve the instrument before its final administration.

Reliability of the Instrument

The internal consistency reliability of the Physics Teachers' Competence Questionnaire was established through a pilot test involving 20 Physics teachers who were not included in the main study. The responses obtained from the pilot administration were analyzed using Cronbach's alpha coefficient to determine the internal consistency of the instrument and its subscales. The Cronbach's alpha coefficients obtained were 0.94 for the entire instrument, 0.89 for the Pedagogical Competence Scale, and 0.92 for the Content Competence Scale. The coefficients indicated satisfactory internal consistency for the instrument and its two subscales.

Method of Data Analysis

The data collected were analyzed using descriptive and inferential statistics. Research Questions 1 and 2 were answered using mean and standard deviations, while frequencies and percentages were used to summarize the respondents' demographic characteristics. The mean scores were interpreted

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using a criterion mean of 2.50, calculated as (4+3+2+1)/4. Mean score of 2.50 and above were interpreted as high, whereas mean score below 2.50 were interpreted as low. One-way ANOVA was used to test the three hypotheses. The null hypothesis was rejected when the significance value was less than .05 and the null hypothesis was retained when the significance value was greater than or equal to .05. The analyses were conducted using SPSS version 27.

Presentation of Results

Table 1: Demographic Characteristics of the Respondents

Characteristics	Group	Frequency	Percentage
Gender	Male	34	60.7%
	Female	22	39.3%
Age	20-30 years	6	10.7%
	31-40 years	15	26.8%
	41-50 years	25	44.6%
	51+above	10	17.9%
Highest Academic Qualification	NCE	2	3.6%
	B.Sc. /B.Sc. (Ed)	9	16.1%
	B.Sc. + PGDE	3	5.4%
	M. Ed. /M.Sc.	22	39.3%
	PhD	20	35.7%
Years of Teaching Experience	1-5 years	11	19.6%
	6-10 years	13	23.2%
	11-15 years	14	25.0%
	16 years and above	18	32.1%
School location	Urban	39	69.6%
	Rural	17	30.4%

Research Question 1: What is the level of pedagogical competence of Physics teachers in implementing the Physics curriculum in public senior secondary schools in Imo State?

Table 2: Teachers' Reported Pedagogical Competence in Implementing the Physics Curriculum.

S/N	ITEMS	SA	A	D	SD	MEAN	STD
1	I use a variety of teaching methods (e.g., demonstration, discussion, inquiry) to teach Physics concepts	42 75.0%	14 25.0%			3.75	0.437
2	I can plan lesson notes that align with the Physics curriculum objectives	38 67.9%	18 32.1%			3.68	0.471
3	I effectively use instructional materials to enhance students' understanding of Physics	33 58.9%	18 32.1%	5 8.9%		3.50	0.661
4	I employ practical/laboratory activities to reinforce theoretical concepts	30 53.6%	24 42.9%	2 3.6%		3.50	0.572
5	I adapt my teaching strategies to accommodate students of varying abilities	35 62.5%	18 32.1%	3 5.4%		3.57	0.599

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6	I use formative assessment techniques to monitor students' understanding during lessons	25 44.6%	25 44.6%	5 8.9%	1 1.8%	3.32	0.716
7	I integrate ICT tools/resources in teaching Physics topics	14 25.0%	26 46.4%	7 12.5%	9 16.1%	2.80	0.999
8	I effectively manage classroom activities during practical lessons	29 51.8%	22 39.3%	5 8.9%		3.43	0.657
9	I link Physics concepts to real-life applications during instruction	40 71.4%	14 25.0%	2 3.6%		3.68	0.543
10	I evaluate students' learning outcomes using curriculum-aligned assessment tools	25 44.6%	30 53.6%	1 1.8%		3.43	0.535
Weighted Mean = 3.47							
Criterion Mean = 2.50							

NOTE: SA = Strongly Agree; A = Agree; D = Disagree; SD = Strongly Disagree; Criterion Mean = 2.50

Table 2 show the level of pedagogical competence of teachers in the implementation of the Physics curriculum in public senior secondary schools in Imo State. The overall weighted mean score of 3.47 exceeded the criterion mean of 2.50, indicating that the teachers reported a high level of pedagogical competence. Specifically, teachers reported high competence in using a variety of teaching methods (Mean = 3.75), planning lesson notes aligned with the curriculum (Mean = 3.68), linking Physics concepts to real-life applications (Mean = 3.68), adapting teaching strategies to students' varying abilities (Mean = 3.57), and effectively using instructional materials and practical activities (Mean = 3.50 each). However, the integration of ICT tools and resources in teaching Physics recorded the lowest mean score (Mean = 2.80), although it remained above the criterion mean. Overall, the results suggest that participating Physics teachers reported a high level of pedagogical competence in implementing the Physics curriculum.

Research Question 2: What is the level of content competence of Physics teachers in implementing the Physics curriculum in public senior secondary schools in Imo State?

Table 3: Teachers' Reported Content Competence in Implementing the Physics Curriculum

S/N	ITEMS	SA	A	D	SD	MEAN	STD
1	I have adequate knowledge of Mechanics topics in the Physics curriculum	31 55.4%	23 41.1%	2 3.6%		3.52	0.572
2	I have adequate knowledge of Electricity and Magnetism topics	28 50.0%	26 46.4%	2 3.6%		3.46	0.571
3	I have adequate knowledge of Waves and Optics topics	30 53.6%	24 42.9%	2 3.6%		3.50	0.572
4	I have adequate knowledge of Thermal Physics topics	30 53.6%	21 37.5%	4 7.1%	1 1.8%	3.43	0.710
5	I have adequate knowledge of Modern Physics topics (e.g., atomic, and nuclear physics)	24 42.9%	24 42.9%	8 14.3%		3.29	0.706
6	I am confident explaining abstract Physics concepts to students	26 46.4%	19 33.9%	10 17.9%	1 1.8%	3.25	0.815
7	I can solve quantitative/mathematical problems in Physics accurately	25 44.6%	23 41.1%	8 14.3%		3.30	0.711
8	I keep up to date with new developments and content in Physics	26 46.4%	23 41.1%	6 10.7%	1 1.8%	3.32	0.741
9	I can correct students' misconceptions in Physics effectively	31 55.4%	21 37.5%	4 7.1%		3.48	0.632

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10	I can relate different topics within the Physics curriculum coherently	28 50.0%	24 42.9%	4 7.1%	3.43	0.628
Weighted Mean = 3.40						
Criterion Mean = 2.50						

Table 3 presents the teachers' reported content competence in implementing of the Physics curriculum in public senior secondary schools in Imo State. The overall weighted mean score of 3.40 exceeded the criterion mean of 2.50, indicating that the teachers possessed a high level of content competence. Teachers reported high competence in their knowledge of Mechanics (Mean = 3.52), Waves and Optics (Mean = 3.50), correcting students' misconceptions in Physics (Mean = 3.48), and knowledge of Electricity and Magnetism (Mean = 3.46). They also demonstrated competence in relating different Physics topics coherently and in their knowledge of Thermal Physics (Mean = 3.43 each). The lowest mean score was recorded for confidence in explaining abstract Physics concepts (Mean = 3.25), although it remained above the criterion mean. Overall, the findings indicate that the participating Physics teachers reported a high level of content competence in implementing the Physics curriculum in public senior secondary schools in Imo State.

Hypothesis 1: There is no significant difference in the reported pedagogical competence of Physics teachers according to years of teaching experience.

Table 4: One-Way ANOVA of Reported Pedagogical Competence by Years of Teaching Experience.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	71.016	3	23.672	1.416	.249
Within Groups	869.538	52	16.722		
Total	940.554	55			

Table 4 shows that the difference in reported pedagogical competence among the categories of teaching experience was not statistically significant, $F_{(3, 52)} = 1.416$, $p = .249$. Since the p-value is greater than the 0.05 level of significance, the null hypothesis was not rejected. Therefore, the null hypothesis was not rejected. The results indicates that the participating teachers reported pedagogical competence did not differ significantly according to years of teaching experience.

Hypothesis 2: There is no significant difference in the reported content competence of Physics teachers according to years of teaching experience.

Table 5: One-Way ANOVA of Reported Content Competence by Years of Teaching Experience

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	22.141	3	7.380	.284	.837
Within Groups	1350.842	52	25.978		
Total	1372.982	55			

Table 5 shows that the difference in reported content competence among the categories of teaching experience was not statistically significant, $F_{(3, 52)} = 0.284$, $p = .837$. Since the p-value is greater than the 0.05 level of significance, the null hypothesis was not rejected. Therefore, the null hypothesis was not rejected. The result indicates that the participating teachers' reported content competence did not differ significantly according to years of teaching experience.

Hypothesis 3: There is no significant difference in the overall competence of Physics teachers according to academic qualification.

Table 6: One-Way ANOVA of Overall Reported Competence by Academic Qualification.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	208.772	4	52.193	2.286	.073
Within Groups	1164.210	51	22.828		

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Total	1372.982	55

Table 6 shows that the difference in overall reported competence among the academic qualification groups was not statistically significant, F (4, 51) = 2.286, p = .073. Since the p-value (.073) is greater than the 0.05 level of significance, the null hypothesis was not rejected. This implies that academic qualification did not significantly influence the competence of the Physics teachers.

Discussion of Findings

The weighted mean score of 3.47 indicates that the participating Physics teachers reported a high level of pedagogical competence in implementing the Physics curriculum in public senior secondary schools in Imo State, which means that the teachers generally believed they were able to implement the Physics curriculum effectively in the classroom. This finding is consistent with literature emphasizing that effective Physics teaching requires not only subject-matter knowledge but also the ability to select appropriate teaching strategies, present concepts meaningfully, assess students' learning, and respond to their needs. Krepf et al. (2018) reported variation in the knowledge that teachers draw upon in the interpretation of classroom instruction, and Ibrahim et al. (2014) identified differences between the pedagogical content knowledge held by expert and novice lecturers. Jang et al. (2013) and Karal and Alev (2016) also found that PCK is formed in the process of teacher preparation and professional experience. This finding supports the view that pedagogical knowledge is a vital component of competent Physics teaching. A high rating of the use of varied teaching methods, and adaptation of teaching methods to students with varying abilities, also indicates teachers' self-perceptions of using learner-oriented and curriculum-related practices. This could be because they are professionally prepared and have been exposed to classroom instruction, giving them experiences to develop and use pedagogical knowledge. This finding is also consistent with the results of Freitas et al. (2004) and Caleon et al. (2018), who showed the importance of teachers' professional knowledge and classroom practices in Physics teaching. However, the low rating of ICT integration suggests that high pedagogical competence did not apply equally to all contemporary teaching practices. This may be associated with unequal access to technological resources, limited experience in using ICT for instruction, or inadequate opportunities for technology-related professional development. Therefore, while the teachers in general showed good pedagogical competence, the lesser competence in using ICTs indicated that pedagogical competence can be uneven in some pedagogical aspects of teaching and learning.

The results also indicate that the participating teachers reported a high level of content competence, which is also in support of the importance of teachers' content competence in implementing the curriculum. This finding is consistent with Etkina et al. (2018), who emphasized the need to assess teachers' content knowledge specifically related to Physics teaching. It is also aligned with the argument of Ramma et al. (2024) that the teachers' content knowledge is still a concern when teaching specific Physics concepts. The present finding is also consistent with the argument of Chan and Van Driel (2026), namely that content knowledge and pedagogical content knowledge impact teachers' noticing and interpreting in the classroom. The teachers' high rating in Mechanics, Waves and Optics, Electricity and Magnetism, Thermal Physics, and their reported capacity to correct students' misconceptions indicate they felt they were knowledgeable in important parts of the Physics curriculum. The teachers also reported an ability to link topics coherently, thus suggesting an understanding of the inter-connections of physics knowledge, a necessary element for the implementation of the curriculum meaningfully. However, the comparison of the lower means in the content competence of explaining abstract Physics concepts and solving quantitative or mathematical problems indicates that content competence may not be fully developed in all aspects

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of Physics knowledge. This is significant because Physics demands conceptual understanding as well as factual knowledge, the ability to reason mathematically, and the ability to explain abstract phenomena. This pattern may reflect the difficulty teachers encounter when transforming complex or abstract disciplinary content into explanations that students can easily understand. This observation aligns with the findings of Ramma et al. (2024), that there are gaps in teachers' content knowledge in certain Physics topics, and Chan and Van Driel (2026), who highlighted the importance of content knowledge in teachers' deconstruction of classroom scenarios.

The finding that years of teaching experience did not produce a significant difference in teachers reported pedagogical competence suggests that teaching experience alone may not guarantee higher professional competence. This result is consistent Mirzaei et al. (2020) who, in their study of the experienced and inexperienced Physics teachers' reflective teaching competency, proposed that the differences in professional competence cannot be easily attributed to the number of years a teacher has spent in the profession. It also gives a much-needed qualification to the studies of Freitas et al. (2004) and Caleon et al. (2018), which found differences between the practices or beliefs of experienced and beginning Physics teachers. This apparent difference between the present finding and the foregoing studies could be attributed to the differences in the nature of the competence measured, in the educational context, and in the teacher characteristics. This may suggest that the pedagogical competence is more related to the quality and continuity of professional learning than to the length of service since no significant difference was found in the present study. Likewise, the content competence of the teachers was not significantly affected by years of teaching experience. The result indicates that the teachers' reported content competence did not differ significantly across the categories of teaching experience. The findings are in line with Mirzaei et al. (2020), who warned against assuming that the experience of teaching is an adequate basis for explaining differences in teachers' professional competence. However, it may seem to contradict the overall findings of Krepf et al. (2018), Ibrahim et al. (2014), and Jang et al. (2013) regarding differences in teachers' knowledge based on expert or experienced teachers. The difference could arise because the professional experience does not necessarily lead teachers to new knowledge of Physics, nor does it necessarily enhance their disciplinary understanding systematically. Content competence could, however, rely on prior education, ongoing professional learning, self-learning, and experiences of Physics developments. Significant differences may not have been apparent because of the use of a self-reported questionnaire, where teachers with dissimilar experience grades may have evaluated themselves in the same way. The result should not be interpreted as evidence that teaching experience has no relationship with content competence. Rather, it indicates that no statistically significant difference was detected in the sample.

The absence of a statistically significant difference in overall reported competence according to academic qualification is noteworthy, since it is usually believed that academic qualification is a measure of teacher preparation. While the difference was not significant at the .05 level. The finding is contrasting to the findings of Nigerian studies in teacher qualification and quality as reported by Tella and Aduramo (2016), Shedrack and Nduudee (2023), and Eyenaka et al. (2023), which looked at teacher qualification and quality in the context of Physics learning outcomes of students. However, the present study examined teachers' reported competence directly rather than using students' learning outcomes as the primary measure. Therefore, evidence that teacher qualification is associated with student outcomes in one context does not necessarily imply that qualification will produce statistically significant differences in teachers' self-reported competence in another context.

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Another reason for the lack of a significant difference may be due to the composition of the sample, because a sizable proportion of the respondents had relatively high academic qualifications; 39.3% held M. Ed /M.Sc. degrees and 35.7% held PhDs, with only two teachers holding NCE qualifications and nine holding B.Sc. /B.Sc. Ed. Moreover, those with more advanced academic training may also have improved theoretical knowledge or disciplinary knowledge, but not necessarily have equivalent gains in classroom skills. This is consistent with the distinction between subject-matter knowledge and the ability to apply that knowledge effectively in instruction. Both Etkina et al. (2018) and Chan and Van Driel (2026) highlight the need to have the kind of knowledge that is specific to the teaching of Physics and not just to the content area.

Overall, the findings indicate that Physics teachers in the study perceived themselves as highly competent in both pedagogical and content dimensions of curriculum implementation, while years of teaching experience and academic qualification did not significantly differentiate their competence. The results support the view that content and pedagogical knowledge are important to the effective implementation of the Physics curriculum and should not be assessed solely through demographic or professional characteristics. This interpretation is corroborated by Gess-Newsome et al. (2019), who reported a relationship between teachers' pedagogical content knowledge, classroom practice and student achievement, and Keller et al. (2017), who reported a relationship between teachers' pedagogical content knowledge and motivation, and students' achievement and interest. The findings also substantiate Omosewo's (2009) call for the training and retraining of Physics teachers in Nigeria. In this study, a direct relationship between longer teaching experience and higher teaching skills, as well as between higher academic qualification and higher teaching skills, was not observed, so the skill of teaching the physics curriculum should be continuously improved according to the specific requirements of Physics curriculum implementation. The lower ratings on aspects such as ICT integration, explaining abstract concepts and quantitative problem solving also point to areas that might need specific attention. There is an implication that teacher development programmes, school authorities and education policymakers should focus more on continuous pedagogical, practice-oriented professional development, strengthening teachers' pedagogical approaches, ICT integration in Physics education, explanation of abstract concepts, and Physics problem-solving competence, rather than relying solely on years of service or academic qualification as indicators of teachers' preparedness to implement the Physics curriculum effectively.

Conclusion

The study concludes that the participating Physics teachers in public senior secondary schools in Imo State reported high levels of pedagogical and content competence in implementing the Physics curriculum. However, neither years of teaching experience nor academic qualification was associated with a statistically significant difference in the teachers' reported competence. This finding suggests that professional preparation and continuous development may be more relevant to teachers' competence than years of experience or academic qualification considered in isolation.

The study has some limitations. First, the use of convenience sampling and a small sample limit the generalizability of the findings. Second, the data were obtained through self-report, which may have introduced social-desirability and self-assessment bias. Third, cross-sectional design does not permit causal conclusions regarding the relationship between teachers' characteristics and competence. Future studies should use larger and more representative samples, objective assessment of teachers' Physics knowledge, classroom observations and mixed methods designs. Therefore, sustained professional development should be provided to further strengthen teachers' pedagogical and content

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competence, particularly in ICT integration and the explanation of abstract Physics concepts, and quantitative problem-solving.

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Comparative Assessment of Motivation and Interpersonal Skills on Academic Achievement in Chemistry among Post-Basic School Students in Gombe State, Nigeria

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Abstract
This study investigated the predictive power of motivation and interpersonal skills on students' academic achievement in chemistry in post-basic schools in Gombe State, Nigeria. A predictive correlational research design was adopted for the study. The population comprised 10,038 SS III students offering Chemistry in 71 post-basic schools. A sample of 370 students was selected using a multistage sampling technique. Data were collected using the Chemistry Students' Motivation and Interpersonal Skills Questionnaire (CSMISQ), adapted from the Academic Competency Evaluation Scale–Student Form, and the Chemistry Result Proforma (CRP). The CSMISQ consisted of 25 items, comprising 15 motivation and 10 interpersonal skills items measured on a five-point Likert scale. The instrument was validated by three experts, while Cronbach's alpha yielded reliability coefficients of 0.78 and 0.81 for the motivation and interpersonal skills subscales, respectively. Data were analyzed using linear and multiple regression. The findings showed that students' motivation significantly predicted academic achievement in Chemistry ($R = .565$, $R^2 = .320$, $t(368) = 13.145$, $p < .05$). Students' interpersonal skills also had a significant predictive power on their academic achievement ($R = .443$, $R^2 = .196$, $t(368) = 9.471$, $p < .05$). Furthermore, students' motivation and interpersonal skills jointly had a significant predictive power on their academic achievement in Chemistry ($R = .643$, $R^2 = .414$, $F(2, 367) = 129.578$, $p < .05$). The study concluded that motivation and interpersonal skills are significant predictors of academic achievement in Chemistry. It was recommended that Schools and teacher education programmes should integrate motivational and interpersonal-skill development into Chemistry instruction through supportive, collaborative and student-centred learning environments that promote both academic engagement and effective social interaction.
Keywords: Motivation, interpersonal skills, academic achievement, Chemistry

Introduction
Science education is fundamental to the development of scientific literacy, problem-solving ability, and the capacity to understand and respond to scientific and technological developments. It provides learners with knowledge and skills needed to understand the natural world and participate meaningfully in a society increasingly shaped by science and technology. The Federal Government of Nigeria (FGN, 2014) recognizes science education as an important component of the national education system, with subjects such as Biology, Physics, Chemistry, and Agricultural Science providing foundations for further study in science-related fields. Among these subjects, Chemistry

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occupies a particularly important position because it provides an understanding of the composition, properties, and transformations of matter. Bochet (2023) emphasized the importance of Chemistry education in developing scientific understanding, while Pernaa et al. (2022) highlighted its relevance to contemporary issues such as sustainability and environmental challenges. Chemistry education also provides foundational knowledge for professional fields including medicine, engineering, agriculture, and other science- and technology-related occupations (Khanam, 2018). Consequently, students' achievement in Chemistry remains an important indicator of the effectiveness of science education at the post-basic school level. Despite the importance of Chemistry, students' academic achievement in the subject remains a concern, particularly in Gombe State. Reports of the West African Examinations Council (WAEC) indicated that 77.02%, 89.89%, and 85.45% of candidates who sat for the West African Senior School Certificate Examination (WASSCE) obtained grades A1–C6 in 2019, 2020, and 2021, respectively. In contrast, data reported by the Gombe State Ministry of Education indicated that only 27%, 32%, 36%, and 39% of candidates obtained grades C6–A1 in 2019, 2020, 2021, and 2022, respectively. Although the state-level figures showed a gradual improvement across the period, the proportion of students attaining the stated grades remained considerably below the national figures. This situation is important because inadequate achievement in Chemistry may restrict students' opportunities to meet entry requirements for further study in science- and professionally oriented programmes. The persistent concern therefore creates a need to examine factors that may help explain differences in students' academic achievement in Chemistry.

Previous studies have identified several factors associated with students' achievement in Chemistry. Apu (2020), for instance, reported that students' attitude, availability of learning resources, student–teacher interpersonal relationships, and regularity of attendance were associated with Chemistry achievement. Similarly, Sibomana et al. (2021) identified the abstract nature of chemical concepts, limited opportunities for practical experimentation, and inadequate learner engagement among factors associated with low achievement in Chemistry. Chinda and Pepple (2021) also reported associations between teacher-related factors, including teachers' qualifications, experience, and training, and students' achievement in Chemistry. While these findings demonstrate that Chemistry achievement is influenced by a range of instructional, environmental, and learner-related factors, they also suggest the need to examine psychosocial characteristics of learners that may contribute to their academic outcomes. Two such characteristics that warrant attention are students' motivation and interpersonal skills. Students' motivation is an important psychological construct in understanding academic engagement and achievement. Ryan and Deci (2020), from the perspective of self-determination theory, distinguish between intrinsic and extrinsic forms of motivation and explain how motivational processes influence the initiation, direction, and persistence of behaviour. In educational settings, motivation is closely associated with students' willingness to engage with learning activities and sustain effort in the face of academic challenges. Martin (2017) similarly noted the close conceptual relationship between motivation and academic engagement, while Pintrich (2003) emphasized the importance of motivational processes in regulating students' learning behaviour. In addition, students' motivational orientations may be shaped by features of the learning environment, including instructional practices, teacher support, and social interactions (Wigfield & Eccles, 2020). Thus, students who are sufficiently motivated may be more willing to invest effort, persist with difficult learning tasks, and engage actively in Chemistry learning.

Empirical studies have generally reported positive associations between students' motivation and academic achievement, although the strength and consistency of the relationship vary across

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contexts. For example, Huang et al. (2025), in a study of low-income college students in China, found that intrinsic motivation was a significant predictor of students' Grade Point Average. Sofyan et al. (2025) also reported a significant relationship between learning motivation and academic achievement among high school students in Indonesia. Bin Abdulrahman et al. (2023) similarly found significant relationships between intrinsic and extrinsic motivation and academic performance among medical students in Saudi Arabia. However, Yasminei et al. (2023) reported no substantial relationship between motivation and academic achievement among secondary school students in selected Arab schools in Malaysia. This contrasting finding suggests that the relationship between motivation and achievement may depend partly on educational, cultural, and contextual conditions.

Evidence from Nigeria provides further support for examining motivation as a predictor of Chemistry achievement. A study by Akanbi and Okunuga (2023) reported that intrinsic and extrinsic motivation significantly predicted Chemistry achievement among secondary school students in Lagos State, with intrinsic motivation showing the stronger predictive contribution. In Ekiti State, Boris (2021) found a significant positive relationship between students' motivation and academic achievement in Chemistry, while Oyekola et al. (2020) similarly reported a positive relationship between motivation and Chemistry achievement among secondary school students in Oyo State. Comparable findings have also been reported in other school subjects. Okoro (2021) found that motivation was associated with students' academic achievement in Social Studies in Taraba State, while Radda et al. (2024) reported a significant relationship between motivation and academic performance in Islamic Studies in Katsina State. Baji and Paul (2024) likewise found a significant relationship between motivation and Biology achievement among secondary school students in Niger State. Taken together, these studies provide substantial evidence that motivation may be an important predictor of academic achievement; however, motivation does not operate in isolation from students' social and interpersonal experiences within the learning environment.

Interpersonal skills represent another learner-related factor that may be relevant to academic achievement. They refer broadly to the abilities and behaviours through which individuals communicate, cooperate, establish relationships, and interact effectively with others. In the school environment, such skills may include communication, active listening, cooperation, teamwork, empathy, and appropriate social interaction. DiPerna and Elliott (2002) conceptualized interpersonal skills within the broader framework of academic enablers, emphasizing behaviours that facilitate students' successful functioning in academic settings. These skills are particularly relevant to learning because students regularly interact with teachers and peers, seek assistance, exchange ideas, participate in group activities, and engage in collaborative academic tasks. Effective interpersonal functioning can therefore create conditions that facilitate communication, help-seeking, cooperation, and productive classroom interaction (Cavazos, 2013).

Research evidence also indicates that interpersonal functioning is associated with students' academic outcomes. Zhang (2022) reported a significant relationship between teachers' interpersonal behaviours and learners' academic achievement, emphasizing the importance of interpersonal processes within educational settings. Sukarna (2021) found that students' interpersonal communication skills significantly influenced learning outcomes in Mechanical Engineering, while Awan and Amin (2021) reported significant associations between interpersonal competencies and academic performance. Similarly, Alva et al. (2021) found a positive relationship between students' interpersonal relationships and academic performance among high school students. Kiuru et al.

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(2020) further demonstrated that adolescents' interpersonal relationships were associated with school well-being and academic achievement during educational transitions. These findings suggest that interpersonal skills may complement students' motivational resources by facilitating the social behaviours through which learners participate effectively in classroom and collaborative learning activities.

The consideration of motivation and interpersonal skills together is particularly relevant because academic achievement is unlikely to be adequately explained by a single learner characteristic. From the perspective of self-determination theory, students' motivation is influenced by social contexts that support effective engagement and psychological functioning (Ryan & Deci, 2020). Similarly, the academic-enablers perspective of DiPerna and Elliott (2002) recognizes social and behavioural competencies as important resources for successful academic functioning. Examining the two variables simultaneously may therefore provide a broader understanding of the psychosocial characteristics associated with students' academic achievement in Chemistry than examining either variable independently. However, important gaps remain in the existing empirical literature. Studies conducted outside Nigeria have established relationships between motivation and academic achievement (Huang et al., 2025; Sofyan et al., 2025) or between interpersonal functioning and academic outcomes (Zhang, 2022; Kiuru et al., 2020), but their educational, cultural, and subject contexts differ from post-basic Chemistry education in Gombe State. Within Nigeria, Akanbi and Okunuga (2023), Boris (2021), and Oyekola et al. (2020) provide evidence of the predictive or correlational relationship between motivation and Chemistry achievement, but these studies did not incorporate interpersonal skills into the predictive model. Consequently, these studies were conducted in states other than Gombe State. Consequently, there is limited empirical evidence on whether motivation and interpersonal skills individually and jointly predict students' academic achievement in Chemistry among post-basic school students in Gombe State. The present study addresses this gap by examining the predictive power of students' motivation and interpersonal skills on academic achievement in Chemistry in post-basic schools in Gombe State, Nigeria.

Purpose of the Study

The purpose of this study is to determine the extent to which academic students' motivation and interpersonal skills predict their academic achievement in chemistry in post basic schools of Gombe State. Specifically, the study intends to determine;

1. The predictive power of students' motivation on their academic achievement in chemistry
2. The predictive power of students' interpersonal skills on their academic achievement in chemistry.
3. The predictive power of students' motivation and interpersonal skills jointly on their academic achievement in chemistry.

Research Questions

The following research questions were raised to guide the study;

1. What is the predictive power of students' motivation on their academic achievement in chemistry?
2. What is the predictive power of students' interpersonal skills on their academic achievement in chemistry?
3. What is the predictive power of students' motivation and interpersonal skills jointly on their academic achievement in chemistry?

Null Hypotheses

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The following hypothesis were formulated to be tested at 0.05 level of significance:

H_{o1}: The predictive power of students' motivation on their academic achievement in chemistry is not significant.

H_{o2}: The predictive power of students' interpersonal skills on their academic achievement in chemistry is not significant.

H_{o3}: The predictive power of students' motivation and interpersonal skills jointly on their academic achievement in chemistry is not significant.

Research Methodology

This study adopted a predictive correlational design. The design was considered appropriate because the study sought to determine the extent to which students' motivation and interpersonal skills statistically predict their academic achievement in Chemistry without manipulating any of the variables (s) (Sani , 2017). The population for the study comprised all the SS III students in Chemistry in (2023/2024 session) in Gombe state totaling 10,038 of the 71 Chemistry-offering post basic schools within the 11 Local Government Areas and three educational zones of the state. The sample size of this study was 370 students based on (Adam, 2020) who were selected using multi stage sampling technique. The instruments for data collection for this study were Chemistry Students' Motivation and Interpersonal skills Questionnaire (CSMISQ) adapted from student form of Academic Competency Evaluation scale (ACES-Student) by DiPerna and Elliots (2018), and Chemistry Result Proforma (CRP). The CSMISQ consists of 25 items across the two sections: Section A contains information about the personal information. While section B contain 15 items for motivation and also 10 items on interpersonal skills measured on five Likert-type scale: Very High Level = 5 points, High Level = 4 points, Moderate Level = 3 points, Low Level = 2 points and Very Low Level = 1 point. The CRP on the other hand was designed by the researcher and used for collecting already existing scores and used as students' academic achievement in Chemistry.

The face and construct validity of the CSMISQ were established by three experts, while Cronbach's alpha yielded reliability coefficients of 0.78 for the motivation subscale and 0.81 for the interpersonal skills subscale during the trial testing. The data collected for the study were analyzed using Linear regression. The research questions were answered using correlation coefficient (R). The range of the R-value is ±0.0-0.29 (low), ±0.30 to 0.8 (moderate), and ±0.81 (strong) (Ratner, 2009). Regression t-tests were used to test hypotheses one and two at the 0.05 level of significance. Regression ANOVA was used to test hypothesis three at the same level of significance. Regression t-tests were used to examine the unique predictive power of each motivation and interpersonal skill (hypotheses 1–2), while regression ANOVA was used to test whether motivation and interpersonal skill jointly explained a significant proportion of academic achievement in Chemistry (hypothesis 3).

Presentation of Results

Research Question 1: What is the predictive power of students' motivation on their academic achievement in chemistry?

Table 1: Regression Model Summary for Students' Motivation Predicting Academic Achievement in Chemistry

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.565[a]	.320	.318	2.80583

a. Predictors: (Constant), Students' motivation in learning Chemistry

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The results in Table 10b shows that Students' motivation have moderate positive power (R = .565) on students' academic achievement in Chemistry. The R^2 of 0.320 indicates that 32.0% of the variation in students' academic achievement in Chemistry is explained by Students' motivation. This indicates Students' motivation is a good predictor of students' academic achievement in Chemistry.

H_{o1}: The predictive power of students' motivation on their academic achievement in chemistry is not significant.

Table 2: Regression Coefficients for the Prediction of Academic Achievement in Chemistry from Students' motivation

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.017	1.252		8.803	.000
	Students' motivation	.608	.046	.565	13.145	.000

a. Dependent Variable: Students' academic achievement

Result in Table 2 shows that t(1, 368) = 13.145; p=0.000< 0.05 for the predictive power of the mastery goals on the pre service chemistry teachers' CGPA. The null hypothesis is rejected, because the observed p-value of 0.000 is less than of the significant level (0.05). Therefore, students' motivation has a significant predictive power on students' academic achievement.

Research Question 2: What is the predictive power of students' interpersonal skills on their academic achievement in chemistry?

Table 3: Regression Model Summary for Students' Interpersonal skills Predicting Academic Achievement in Chemistry

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.443[a]	.196	.194	3.04990

a. Predictors: (Constant), Students' interpersonal skills in learning Chemistry

The results in Table 3 shows that Students' Interpersonal Skills have moderate positive power (R = .443) on students' academic achievement in Chemistry. The R^2 of 0.196 indicates that 19.6% of the variation in students' academic achievement in Chemistry is explained by Students' Interpersonal Skills. This indicates Students' Interpersonal Skill is a good predictor of students' academic achievement in Chemistry.

H_{o2}: The predictive power of students' interpersonal skills on their academic achievement in chemistry is not significant.

Table 4: Regression Coefficients for the Prediction of Academic Achievement in Chemistry from Students' Interpersonal Skills

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	16.241	1.184		13.713	.000
	Students' Interpersonal	.407	.043	.443	9.471	.000

a. Dependent Variable: Students' Academic Achievement

Result in Table 4 shows that t(1, 368) = 9.741; p=0.000< 0.05 for the predictive power of students' interpersonal skills on students' academic achievement. The null hypothesis is rejected, because the observed p-value of 0.000 is less than of the significant level (0.05). Therefore, students' interpersonal skills have a significant predictive power on students' academic achievement.

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Research Question 3: What is the predictive power of students' motivation and interpersonal skills jointly on their academic achievement in chemistry?

Table 5: Regression Model Summary for Students' Motivation and Interpersonal Skills Jointly Predicting Academic Achievement in Chemistry

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.643[a]	.414	.411	2.60757

a. Predictors: (Constant), Students' Motivation, Students' Interpersonal Skills

The results in Table 5 show that Students' Motivation and Interpersonal Skills jointly have moderate positive power (R = .643) on students' academic achievement in Chemistry. The R^2 of 0.414 indicates that 41.4% of the variation in students' academic achievement in Chemistry is explained by Students' Motivation and Interpersonal Skills jointly. This indicates Students' Motivation and Interpersonal Skills jointly is a good predictor of students' academic achievement in Chemistry.

H_{o3}: The predictive power of students' motivation and interpersonal skills jointly on their academic achievement in chemistry is not significant

Table 6: ANOVA for the Multiple Regression of Students' Motivation and Interpersonal Skills on Academic Achievement in Chemistry

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	1762.115	2	881.058	129.578	.000[b]
Residual	2495.391	367	6.799		
Total	4257.507	369			

a. Dependent Variable: Students' Academic Achievement in Chemistry

b. Predictors: (Constant), Students' Motivation, Students' Interpersonal Skills

The results in Table 6 show that $F(2, 367) = 129.578$, $p < 0.05$ for the predictive power of students' motivation and interpersonal skills jointly on academic achievement in Chemistry. Since the p-value 0.000 is less than the 0.05 level of significance, the null hypothesis is rejected. Therefore, students' motivation and interpersonal skills jointly have a significant predictive power on students' academic achievement in Chemistry.

Discussion of Findings

The first finding revealed that students' motivation significantly predicted their academic achievement in Chemistry. This finding agrees with Huang et al. (2025), Sofyan et al. (2025), Bin Abdulrahman et al. (2023), Akanbi and Okunuga (2023), and Oyekola et al. (2020), who reported significant positive relationships between students' motivation and academic achievement. However, it contradicts Yasminei et al. (2023), who found no significant relationship between motivation and academic achievement. The difference may be attributed to variations in educational, cultural and subject contexts.

The second finding established that students' interpersonal skills significantly predicted their academic achievement in Chemistry. This finding is consistent with Zhang (2022), Sukarna (2021), Awan and Amin (2021), Alva et al. (2021), and Kiuru et al. (2020), who found that interpersonal relationships, communication, teamwork and social skills were positively associated with students' academic performance. This may be because interpersonal skills facilitate effective communication, cooperation, peer interaction, help-seeking and collaborative learning.

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The third finding showed that students' motivation and interpersonal skills jointly significantly predicted their academic achievement in Chemistry. This finding indicates that academic achievement may be enhanced when students possess both the willingness to learn and the ability to interact effectively with others. It is supported by studies linking motivation (Huang et al., 2025; Sofyan et al., 2025; Akanbi & Okunuga, 2023) and interpersonal skills (Zhang, 2022; Alva et al., 2021; Kiuru et al., 2020) with academic performance. The finding therefore highlights the importance of considering both factors simultaneously in understanding Chemistry students' academic achievement.

Conclusion

This study concludes that students' motivation and interpersonal skills are significant predictors of academic achievement in Chemistry, demonstrating that academic success is influenced by both students' willingness to learn and their ability to interact effectively with others. Motivation promotes students' interest, effort and commitment to learning, while interpersonal skills enhance communication, cooperation, peer interaction and collaborative learning. The joint contribution of these factors provides a more comprehensive explanation of students' academic achievement than either factor considered independently. Therefore, students who are motivated to learn and possess effective interpersonal skills are more likely to attain better academic outcomes in Chemistry. The study consequently recommends that Chemistry teaching and teacher education programmes foster supportive learning environments that strengthen students' motivation while providing opportunities for the development of effective interpersonal skills.

Recommendations

1. Chemistry teachers should adopt motivational teaching practices, such as setting achievable learning goals, providing constructive feedback and relating Chemistry concepts to students' real-life experiences, to strengthen students' motivation and improve academic achievement.

2. Chemistry teachers should incorporate more collaborative learning activities, such as group discussions, peer tutoring and practical teamwork, to develop students' interpersonal skills and enhance their academic achievement.

3. Schools and teacher education programmes should integrate motivational and interpersonal-skill development into Chemistry instruction through supportive, collaborative and student-centred learning environments that promote both academic engagement and effective social interaction.

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Assessment of Safety Training and Transportation Safety on Teachers' Productivity among Public Primary Schools in North-East, Nigeria

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Abstract

This study examined the safety status of primary schools; determined the productivity status of primary school teachers; and assessed how safety training and transportation safety contribute to teachers' productivity. The study has two objectives and two research questions. The study was anchored on Maslow's Hierarchy of Needs Theory (1943). A descriptive survey design was adopted. The population comprised all teachers and head teachers in public primary schools in the North East, totaling 153,866. A multi-stage sampling technique was used to purposively select three states (Gombe, Taraba, and Yobe), forty-five primary schools, and 381 respondents consisting of 336 teachers and 45 head teachers. Two validated instruments titled the Primary School Safety Questionnaire (PSSQ) and the Primary School Safety and Teacher Productivity Questionnaire (TPQ) with reliability index of 0.70 and 0.81 respectively, were used for data collection. Descriptive statistics (mean and standard deviation) were employed to answer the research questions. Findings revealed that the safety status of primary schools in the North East is critically low across all measured indicators. The study revealed positive impact of safety training and transportation safety. The study recommends urgent government investment in safety training and transportation safety in the North East.

Keywords: Safety, Training, Transportation, Primary Schools, Teachers, Productivity

Introduction

Safety is a condition of being protected from harm or attack. It relates to the absence of threats to human life and dignity. It is the state of being free from hazard, risk, injuries and loss of properties. Safety is the condition of being free from risks, injury, fear and danger (Okaforcha & Okeke, 2023). In this regard therefore, safety is a concept that includes all measures and practice taken to preserve the life, health and integrity of individuals. Essentially, these measures and practices include among others, the safety training for teachers and transportation safety for both teachers and pupils. Safety training refers to the formal process of equipping individuals with the knowledge and skills necessary to prevent, manage, and respond to risks and emergencies. In the educational sector, this includes training in emergency preparedness, first aid, psychosocial support, and threat assessment, particularly for teachers in insecure environments (Domínguez, Mares & Hernández, 2021). In this conviction therefore, safety training in the educational sector has its origins in the broader discipline of occupational health and safety, which emerged in the early 20th century during the industrial revolution when the hazards of workplace conditions demanded systemic regulation. By the mid-20th century, educational institutions, particularly in high-risk or densely populated regions, began adapting these frameworks to safeguard both learners and teaching staff. In postcolonial African states like Nigeria, educational safety began to take shape through health inspections, fire drills, and basic first-aid training (Anokam & Ipem, 2022). However, in many parts of the world, especially in fragile or conflict-affected contexts, the notion of safety training for

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educators remains either underdeveloped or entirely absent, despite overwhelming evidence that teachers frequently operate under high-risk conditions, especially in volatile regions (UNICEF, 2021). In an area like North East zone of Nigeria that is plagued by insurgency and other emergencies, safety training serves a dual function. These are preserving life and sustaining pedagogical continuity. As noted by Duchi, Shaibu and Orebiyi (2023) the role of safety training is especially necessary in the zone where insecurity has led to significant teacher attrition, absenteeism, and declining classroom performance. Global Business Coalition for Education (2015) advocates for training of every staff in each school on security measures. The training should incorporate procedures for evacuation of school buildings and communicating with security officials. According to Uloko and Ada, (2022) schools and their relevant stakeholders acquire wide range of opportunities on training in the knowledge, skills and competencies that will enable them to fully implement critical measures of school safety and security in their respective schools. The training should be on key competencies that teachers and school managers require to carry out their duties as safety providers in schools; for the successful implementation of the Minimum; ensuring learners and school personnel are kept safe and supported to overcome traumatic situations resulting from violence in schools. The intricate relationship between safety training and primary school teachers' productivity in North East cannot be overemphasizing. Several studies (Duchi, et al (2023); Uloko and Ada, (2022) revealed that safety training significantly enhances teacher performance by improving attendance, emotional resilience, lesson delivery, and classroom management in a region plagued by insecurity and educational disruption. Schools that adopted comprehensive safety and psychosocial training have recorded reduced attrition, better learner outcomes, and increased job satisfaction among teachers. Ultimately, integrating safety training into the education system is not just a protective measure but a strategic investment in human capital development and the sustainability of education in conflict-affected regions.

Transportation safety refers to the systematic protection of commuters from physical, psychological, and environmental harm during movement via roads, rail, air, or waterways (Orolade, 2024). It encompasses not only vehicle conditions but also road quality, regulation enforcement, and threat mitigation in transit environments. Yet, in regions afflicted by insecurity, such as the North East of Nigeria where insurgencies and other vices have persisted since 2009, transportation has become not just a logistical challenge but a life-threatening endeavor (Anokam & Ipem, 2022). Primary school teachers' ability to travel to and from work without physical or psychological harm is indispensable. Their productivity is influenced by various internal and external factors, among which transportation stands as a vital yet often underemphasized determinant. The deterioration of roads, vehicular inadequacies, and pervasive insecurity has converged to render daily commutes for primary school teachers not only burdensome but often traumatizing. In this context, transportation safety becomes a decisive factor in determining the extent to which teachers can be physically present, mentally stable, and professionally effective in the classroom. Teachers travelling across the Northeastern region frequently encounter military checkpoints, damaged roadways, and ambush threats, making safe, reliable commuting a persistent challenge (Jummai, 2022). Poor transport access or safety, often makes productivity to be compromised due to fatigue, absenteeism, or psychosocial stress (Anokam & Ipem, 2022; GBCE, 2015). Productivity in the context of teaching is not limited to instructional hours or output alone; it encompasses preparedness, creativity, emotional stability, and sustained motivation (UNESCO, 2020). This study is anchored on two theoretical frameworks: Maslow's Hierarchy of Needs Theory (1954). Maslow's Hierarchy of Needs theory posits that human behaviour is driven by the desire to fulfil a set of hierarchical needs, beginning with physiological

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needs and progressing through safety, love/belonging, esteem, and self-actualization. The theory holds that safety needs including protection from harm, security, and stability must be satisfied before individuals can pursue higher-level goals such as productivity, creativity, and professional development (Ihensekien & Joel, 2023). Applied to this study, Maslow's framework provides insight into how the disruption of basic safety needs undermines teacher productivity in conflict-affected regions. For teachers in North East Nigeria, persistent insecurity directly inhibits their ability to concentrate, innovate, and remain present in school, thereby affecting their effectiveness and long-term professional engagement. In recent times, studies that bear relevance with the current one have been conducted globally. For instance, Masath, Mattonet, Hermenau, Nkuba, & Hecker (2023) investigated the effectiveness of the preventative intervention Interaction Competencies with Children—for Teachers (ICC-T) in reducing violent discipline by teachers in a two-arm matched cluster-randomized controlled trial. The sample comprised teachers (*n*=173, 53.7% female) and students (*n*=914, 50.5% girls) from 12 public primary schools from six regions in Tanzania. Finding of the study revealed that *ICC-T* may positively change teachers' violent disciplining behavior and their attitudes towards violent discipline. The reviewed study is relevant to the present one since it tested the effectiveness of the preventative intervention Interaction Competencies with Children—for Teachers. However, the study adopted a two-arm matched cluster-randomized controlled trial as a design while, the present study adopts a descriptive survey design. Furthermore, only 12 public primary schools from six regions in Tanzania were used studied, against the present study which covers ninety schools.

Another study was carried out by Nkuba, Hermenau1, Goesmann and Hecker (2018) on reducing violence by teachers using the preventative intervention interaction competencies with children for teachers (ICC-T): a cluster randomized controlled trial at public secondary schools in Tanzania. The study adopted a cluster randomized controlled trial to assessed attitudes towards and use of violence by teachers (self-reported and reported by students) at eight schools in four regions in Tanzania. Participants' acceptance was high and they reported a good integration of the core elements in their working routine. The significantly stronger decrease in the use of emotional and physical violence reported both by teachers and students as well as the stronger decrease in positive attitudes of teachers towards physical and emotional violence in the intervention schools at follow-up provide initial evidence of the efficacy. The reviewed study is relevant to the present one since it tested the effectiveness of the preventative intervention Interaction Competencies with Children—for Teachers. However, the study adopted a two-arm matched cluster-randomized controlled trial on only 8 public secondary schools from eight regions in Tanzania as a design while, the present study adopts a descriptive survey design. The present study will be carried out in ninety primary schools in a crisis affected North East, Nigeria. Similarly, Fountas, Olowosegun and Basbas (2022) in a study provided an empirical analysis of the factors influencing the injury severities of the accidents that occurred on trips to or from school in Scotland. Using 9-year data from the STATS19 public database, random parameter binary logit models with allowances for heterogeneity in the means were estimated in order to investigate injury severities in urban and rural areas. The results suggested that factors such as the road type, lighting conditions, vehicle type, and age of the driver or casualty constitute the common determinants of injury severities in both urban and rural areas. The study revealed further that, School travel has been a significant source of safety concerns for children, parents, and public authorities and it will continue to be a source of concerns as long as severe accidents continue to emerge during pupils' commute to school. The findings of this study can inform future policy interventions with a focus on traffic calming in the proximity of schools. The reviewed study is

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relevant to the current study in many respects. However, it differs in terms of methodology. The study uses 9-year secondary data from the STATS19 public database and random parameter binary logit models with allowances for heterogeneity. The current study uses primary data and adopts descriptive survey design. The study was conducted in an advanced and relatively peaceful environment. But the current study is in the North East, Nigeria – a region battling with security challenges.

Statement of the Problem

School safety encompasses a wide range of factors that include physical security, emotional well-being, environmental cleanliness, safety training, transport safety and digital safety. Safety in all aspects is paramount to the attainment of set objectives of primary schools. School is regarded as safe when it is devoid of any form of threat to life or danger and it possesses all the basic needs for its operation. Safe school is a situation in which the teachers and learners feel at home, maintain confidence and positive state of mind and are always at ease and happy towards the achievement of educational goals. North East zone has been afflicted with insurgency, kidnapping, school attacks and poor school infrastructure. These challenges not only expose teachers to threats on professional concerns but, extend to personal survival. Despite increasing recognition of the importance of safety training and transportation safety, many primary schools in the North East remain unsafe for operation. Negative reports, such as underdeveloped or entirely absent of safety training as well as low transportation safety (UNICEF, 2021) are some of the leading reasons for teacher absenteeism, poor instructional delivery and decline learning outcomes. A wide gap exists in the implementation of several government policies that seek to address school safety, such as the National Policy on Safety and Security in Schools. Teachers' productivity is to a large extent depended on the conditions under which they operate. Teachers cannot deliver effectively, if they operate in an unsafe, unsuitable and unpredictable environment. Teachers are demoralized and get involved into reduced attendance due to unsafe environment. It encourages attrition and lower performance. These realities prompted this study in order to investigate the extent to which various aspects of safety training and transportation safety contributes to teacher productivity in primary schools.

Objectives of the Study

The main objective of this study is to find out how school safety contributes to primary school teachers' productivity in North East, Nigeria. Specifically, the study intends to:

1. Examine how safety training contributes to primary school teachers' productivity in North East, Nigeria.
2. Determine how transportation safety contributes to primary school teachers' productivity in North East, Nigeria.

Research Questions

The following questions are set in order to guide the research toward achieving its objectives:

1. How does safety training contribute to primary school teachers' productivity in North East, Nigeria?
2. How does transportation safety contribute to primary school teachers' productivity in North East, Nigeria?

Research Methodology

This study adopted a descriptive survey research design. The descriptive survey design was considered appropriate because it enables the systematic collection of data from a large population in order to describe existing conditions, perceptions and practices as accurately as possible, without manipulation of variables (Bloomfield & Fisher, 2019). Thus, the design would allow the researcher

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to obtain quantitative data on various dimensions of school safety and their implications to primary school teachers' productivity.

Table 1: Population

S/N	State	Number of Primary Schools	Number of Head teachers	Number of Teachers
1.	Adamawa state	2, 599	2, 599	26, 862
2.	Bauchi state	3, 401	3, 401	24, 419
3.	Borno state	702	702	21, 356
4.	Gombe state	1, 911	1, 911	17, 847
5.	Taraba state	2, 797	2, 797	26, 124
6.	Yobe state	1, 965	1, 965	10, 418
	Total			
	Grand Total	**13,375**	**13,375**	**127,116** **153,866**

Sources: *UBEC: Digest of Basic Education (2018).*

A multi-stage sampling technique was employed. In Stage 1, three states Gombe, Taraba, and Yobe were purposively selected based on their status as newly created states carved from Bauchi, Gongola/Adamawa, and Borno respectively, and their documented prevalence of safety challenges. In stage 2, fifteen primary schools per state were selected using purposive sampling from one education zone and one local government based on prevalence of safety challenges, bringing a total to forty-five (45) schools. In Stage 3, a sample of 381 respondents was drawn proportionately across the three states based on the corresponding percentage of number of teachers per state. And in each state, teachers are selected based on their experience. Table 2 presents the sample distribution.

Table 2: Sampled Number of Respondents

S/No.	State	Number of Primary Schools	Number of Sampled Schools	Number of Head Teachers	Sampled Number of Head Teachers	Number of Teachers	Sampled Number of Teachers
1.	Gombe	1,911	15	1,911	15	17,847	110
2.	Taraba	2,797	15	2,797	15	26,124	161
3.	Yobe	1,965	15	1,965	15	10,418	65
	Total	6,673	45	6,673	45	54,389	336
	Grand Total						

Source: Fieldwork 2026

Two instruments were used for data collection: these are the Primary School Safety Questionnaire (PSSQ) and Teachers Productivity Questionnaire (TPQ) administered to both the head teachers and teachers. PSSQ was made to generate information on four (4) objectives of the study that relates to safety in primary schools. Whereas TPQ was used to generate information on one (1) objective that relates to teacher productivity. Both instruments were structured on a four-point modified Likert scale (Strongly Disagree = 1 to Strongly Agree = 4) and were validated by three experts, one each from Science and Vocational Education, Adult Education and Extension Services and Curriculum Studies and Educational Technology departments in the Faculty of Education and Extension Services, UDUS. Reliability index was established using the test-retest method, yielding an overall reliability coefficient of 0.81 for PSSQ and 0.78 for TPQ. Based on these coefficients, the instruments were considered reliable and suitable for data collection. Data were analyzed using descriptive

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statistics (mean and standard deviation) for the research questions, with a benchmark mean of 2.50 serving as the decision criterion.

Presentation of Results

The result was based on the two research questions raised and answered in the study;

Research Question 1: How does safety training promote primary school teachers' productivity in North East, Nigeria?

Table 3: Safety Training contribution to Primary School teachers' productivity

S/N	Safety Training Items	X	Std	Remarks
1.	Regular safety training gives me the confidence to focus on any given task without constant fear of workplace hazards.	2.46	1.04	Disagree
2.	Knowledge of first aid allows me to handle minor injuries quickly, minimizing disruptions to instructional time.	2.50	1.15	Agree
3.	Training on emergency evacuation protocols (e.g., fire or security threats) helps to maintain better school order.	2.60	1.14	Agree
4,	Security awareness training specifically tailored to the Northeast context reduces my work-related anxiety.	2.62	1.11	Agree
5.	Participation in safety workshops has reduced my rate of absenteeism caused by stress or safety concerns.	2.49	1.13	Disagree
6.	Safety training has improved my ability to identify and report potential risks before they escalate into accidents.	2.63	1.13	Agree
7.	Overall, the safety skills I have acquired make me feel more professional and competent in my role as a head.	2.61	1.15	Agree

Source: Field work. 2026

Table 3 revealed how safety training contributes to the productivity of primary school teachers in North East, Nigeria. The data indicates mixed results regarding the perceived contribution of these training programs on teacher productivity which was considered in terms of performance and confidence. Notably, respondents disagreed that regular safety training provides the confidence to focus on tasks without fear of hazards with a mean score of 2.46 with corresponding standard deviation of 1.04 and a mean score of 2.49 (standard deviation of 1.13) on question that says participating in safety workshops has effectively reduced absenteeism caused by stress or safety concerns. Conversely, the study found that specific, practical safety skills are perceived as beneficial for productivity. Teachers agreed that training on emergency evacuation protocols helps maintain better school order with a mean score of 2.60 (standard deviation of 1.14) and they reported that security awareness training tailored to the North East context reduces work-related anxiety with mean score of 2.62 and corresponding standard deviation of 1.11. Additionally, respondents agreed that possessing knowledge of first aid allows them to handle minor injuries efficiently, which minimizes disruptions to instructional time with a mean score of 2.50 and corresponding standard deviation of 1.15. Teachers agreed that such training has improved their ability to identify and report potential risks before they escalate into accidents with a mean score of 2.63 (standard deviation of 1.13). Furthermore, there is a consensus that the overall safety skills acquired through these programs make teachers feel more professional and competent in their roles with mean score of 2.61 (standard deviation of 1.15). The findings highlight a positive contribution of safety training to teachers' productivity with 2.56 grand total of mean with corresponding standard deviation of 1.12.

Research Question 2: How does transportation safety contribute to primary school teachers' productivity in North East, Nigeria?

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Table 4: Ways by which transportation safety contributes primary school teachers' productivity

S/N	Transportation Safety Items	X	Std	Remarks
1.	Safe and secure transportation makes staff arrives to school early enough to start duties on time.	2.61	1.15	Agree
2.	Reliable and safe transport options encourage high rate of daily school attendance.	2.58	1.09	Agree
3.	Frequent road safety hazards in this region cause physical exhaustion that negatively impacts on daily service delivery.	2.54	1.11	Agree
4.	Improved transportation safety allows me to stay back for after-school meetings and extracurricular activities.	2.56	1.27	Agree
5.	Knowing that transportation is safe enhances overall job satisfaction and motivation.	2.66	1.19	Agree
6.	I am more likely to remain committed to my current posting if the transportation routes are guaranteed to be safe.	2.50	1.10	Agree
7.	A calm and safe journey to school helps me maintain better emotional balance and patience when managing staff and pupils.	2.63	1.11	Agree

Source: Field work, 2026

Table 4 indicates a generally positive contribution of transportation safety to teachers' productivity as respondents expressed agreement with all seven items presented. This suggest that safe transportation is viewed as a significant factor in facilitating teachers' professional duties. Specifically, majority of the respondents agreed that safe and secure transportation enables them to arrive early for duties with mean scores of 2.61 (standard deviation of 1.15) and encourages a high rate of daily school attendance with mean of 2.58 (standard deviation of 1.09). Furthermore, the results highlight how transportation challenges impact the physical and professional capacity of educators in the region. Majority of the respondents also agreed that frequent road safety hazards contribute to physical exhaustion, which negatively impacts their daily service delivery (mean: 2.54 corresponding to standard deviation 1.11). They also agreed that having improved transportation safety provides the flexibility to stay back for after-school meetings and extracurricular activities (mean: 2.56 and standard deviation: 1.27). Participants agreed that knowing transportation is safe enhances their overall job satisfaction and motivation (mean: 2.66 and standard deviation: 1.19), and they are more likely to remain committed to their current postings if routes are guaranteed to be safe (mean: 2.50, standard deviation: 1.10). Additionally, teachers noted that a calm, safe journey helps them maintain the emotional balance and patience necessary for managing staff and pupils effectively (mean: 2.63, standard deviation: 1.11). Grand total mean stood as 2.58 with corresponding standard deviation of 1.14 demonstrates the psychological and motivational benefits of safe transit in contributing to teacher productivity measured in terms of their commitment and performance.

Summary of Findings

The following are summaries of findings:

1. Safety training in North East Nigeria shows limited impact on reducing general stress-related absenteeism or broad anxiety, teachers recognize its value in contributing to professional competence, improving risk identification, and providing practical skills such as emergency protocols and first aid that directly minimize classroom disruptions.

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2. The findings indicate that safe and reliable transportation of headteachers and teachers is a critical factor for educators, as it positively contributes to their punctuality, daily attendance, physical well-being, professional motivation, and overall capacity to perform effectively in their school roles.

Discussion of Findings

The first finding of this study indicates that while safety training in North East Nigeria shows limited impact on reducing general stress-related absenteeism or broad anxiety, teachers recognize its value in contributing to professional competence, improving risk identification, and providing practical skills such as emergency protocols and first aid that directly minimize classroom disruptions. This finding agrees with the study by Mutegi, Joshua and Kinyua (2023), who determined the effect of workplace safety on employee productivity in manufacturing firms in Kenya which revealed that safety training statistically and positively affects employees' productive time, value-added output, and degree of accomplishment of tasks. This finding also agrees with the study by Younas, Farooq, Khalil-Ur-Rehman and Zreen (2018), who found a positive relationship between training, development, and employee performance in the banking sector of Pakistan. Similarly, Khan and Abdullah (2019) found strong positive correlations between training and development and teacher productivity in Kurdistan, specifically noting improvements in skills, morale, job knowledge, and proficiency as outcomes of training. However, the finding that safety training shows limited impact on reducing general stress-related absenteeism and broad anxiety is consistent with the study by Nkuba, Hermenau, Goesmann and Hecker (2018), who found in their cluster randomized controlled trial at public secondary schools in Tanzania that while a preventative intervention (ICC-T) significantly reduced physical and emotional violent discipline, there were no significant intervention effects on students' internalizing problems, suggesting that structured training does not automatically resolve the deeper psychological distress arising from chronic insecurity.

The second finding of this study reveals that safe and reliable transportation is a critical factor for educators, as it positively contributes to their punctuality, daily attendance, physical well-being, professional motivation, and overall capacity to perform effectively in their school roles. This finding agrees with the study by Nordfjærn and Rundmo (2018), who examined transport risk evaluations associated with past exposure to adverse security events in public transport among a representative sample of Norwegian urban residents and found that individuals previously exposed to adverse security events in public transport reported substantially higher risk perception and worry about experiencing injury. Their finding that elevated probability judgments of experiencing injury in public transport were related to a lower intention of using such transport directly supports the present finding's identification of transportation safety as a determinant of teacher attendance and punctuality, since fear-driven avoidance of unsafe transport inevitably affects teachers' ability to report to school regularly. This finding also agrees with the study by Fountas, et al, (2022), who analyzed injury severities for accidents occurring during school commutes in Scotland over a nine-year period and concluded that school travel has been a significant source of safety concerns for children, parents, and public authorities, and will continue to be so as long as severe accidents persist during the school commute. Furthermore, Kapatsila and Grisé (2025) investigated the impact of physical, social, and security factors on perceived safety on public transit in Canada, found that people who rate the importance of physical, social, or security factors higher tend to feel less safe on transit, with physical factors having the largest negative effect. However, this finding differs from the study by Simsek (2017), who examined transported education in Turkey and concluded that while transported education enhanced equal educational opportunities, transported children experienced

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fatigue and reduced academic performance due to long journey times. The difference may be attributed to contextual disparities: while Simsek's concern was with journey fatigue in a relatively secure environment, the present study's concern is with security-driven transportation risks in a conflict-affected zone, where the nature and severity of the transportation challenge is fundamentally different.

Conclusion

The study concluded that safety training positively enhances teacher productivity in the North East, particularly in terms of practical competence and professional confidence. However, general safety training has limited capacity to address deep-seated, trauma-related absenteeism and broad anxiety arising from chronic insecurity, suggesting that training must be complemented by broader psychosocial support systems. Transportation safety is also an essential but frequently neglected component of teacher welfare and productivity in the North East. The daily commute of teachers through conflict-prone, poorly maintained roads subjects them to physical exhaustion, psychological distress, and heightened risk of harm all of which negatively impact their attendance, punctuality, and classroom performance. Conversely, access to safe and reliable transportation directly enhances teacher motivation, job satisfaction, and professional commitment. Transportation safety must therefore be reconceptualized as a central dimension of educational planning and teacher welfare policy in conflict-affected regions.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Educational authorities should strengthen safety training programs by making them more practical, regular, and context-specific. Training should cover emergency preparedness, conflict management, first aid, risk assessment, and stress management to further enhance teachers' competence and reduce disruptions to instructional activities.
2. Governments and educational stakeholders should improve transportation arrangements for teachers, particularly in rural and insecurity-prone areas. This may include providing staff buses, transportation allowances, or secure transport partnerships to ensure punctuality, regular attendance, and improved teacher performance.

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Correlational Study of Science Process Skills and Academic Achievement in Biology among Secondary School Students in Sokoto State, Nigeria

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Abstract

The study was conducted on correlational study of science process skills and academic achievement among biology secondary school students in sokoto state. Two research objectives, which were corresponded with research questions and research hypotheses, were developed to guide the study. Research design for the study was correlational research design, with population of 24,137 SS II Biology students which a sample of 379 students drawn using Krejcie and Morgan (1971) table for sample size determination. Multistage sampling technique was used to select the schools and participating students. Four instruments were used for data collection, namely; Science Process Skill Acquisition Test (SPSAT) and Biology Achievements Test (BAT). Instruments used were validated by 14 experts. The instruments achieved the reliability coefficients of 0.88 and 0.66 respectively. The data collected were analyzed using Descriptive (Mean, Standard Deviation and Pearson r) and Inferential (Simple Linear Regression and Multiple regressions) Statistics. The analyses of data were based on the research questions and stated null hypotheses of the study, all the hypotheses were tested at 0.05 level of significance. The results show that there was significant, positive but weak relationship between science process skills and the academic achievement in biology among senior secondary school students. Male biology students' Science Process Skills has moderate, positive and significant relationship with their academic achievement, while female biology students science Process Skills has weak, positive and significant relationship with their academic achievement in senior secondary school Sokoto, Nigeria. Based on the findings, recommendations were made among. State Ministries of Education and Science Teachers Associations of Nigeria (STAN) must implement compulsory professional development workshops, which should specifically train biology teachers on how to effectively scaffold basic science process skills within the senior secondary curriculum.

Keywords: Science, Science education, Biology, Science Process Skills, Gender

Introduction

The significance of science in the national development cannot be overemphasized, because it is an important aspect in school curriculum as man's future depends to a large extent on scientific advances and development of productive activities and also for suitable and socio-economic development as well as for technological advancement of the nations. The knowledge of science is therefore required in all countries due to the numerous challenges that are facing them. Science has made it possible for man to know more about the universe through acquisition of science process skills, which require students to be more active in learning, not only as recipients of subject matter (Muchsin & Hamdi, 2021). The process of transmitting the discoveries of science in form of knowledge, skills, attitudes, as well as fostering understanding of how science works to prepare individuals for informed participation in society, future carriers and continued scientific advancement is referred to as science education. Science education emphasizes the teaching and learning of science process, skills and principles. It is also the field of education that focuses on the teaching of science concepts and addressing challenges that students may have with regards to

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science concepts and phenomena. It is very important to the scientific, technological and economic development of any nation that is why every nation must take it serious in all institutions of learning (Jolaoluwa, Mustapha, Salami, Ogundeji & Oluwagbemi, 2024). Science education focuses to put up a scientifically literate society where individual can solve their problems, provide evidence-based decisions and also evaluate information logically (Glaze, 2018). It is also help the students in the development of various skills, focusing on acquiring knowledge. Meaning there should be integration of knowledge and skills by the students for them to fully understand the scientific concepts (Kimba, Giwa, & Libata, 2018). Teaching students how to engage in inquiry is one of the essential goals of science education. In Nigeria, science education is taught in the Senior Secondary School and comprises of as Chemistry, Physics, Agricultural Science, Geography and Biology.

Biology is one of the subjects that deal with how living organisms came into existence and how they interact with one another and with the environment. Biology simply means the study of living things, including plants and animals, or the study of life. It is a natural science that is concerned with the study of living organisms which include their structure, function, growth, distribution and taxonomy (Stencel & Proszewska, 2018). It is one of the subjects at the secondary school level which is related on how to find out about nature systematically and using the scientific method (Zhaoi, Tripp & Liu, 2024). By studying Biology, students learn more about themselves, the world they live in and also equip them with acquisition of science process skills which enhances their academic achievement.
Academic achievement is the extent to which learners have gained from a particular course of instruction. According to Khalid and Abdulrahman (2023) academic achievement refers to a students' progress after they are exposed to educational program. Also, Suman (2020) refers to academic achievement as the extent to which teaching and study has resulted to mastering, outcome of general and specific objectives. Also, Ibrahim and Mohammed (2023) found that poor performance in biology significantly impacts students' career aspirations in health sciences and related fields, as many students develop negative attitudes toward the subject following repeated academic failures. They also added that inadequate teacher preparation in modern pedagogical strategies, limited access to microscopes and other essential laboratory equipment, large class sizes that prevent individualized attention and the abstract nature of microscopic and molecular concepts as primary contributors to persistent low achievement in secondary school biology education. Science process skills (SPS) are set of skills commonly used by scientist for conducting scientific inquiry (Gizaw & Sota, 2023). According to the Sapna (2020) learners interact with their environment in a scientific way, and during the process they find themselves observing, questioning, hypothesizing, predicting, investigating, interpreting and communicating. Also, the SPS emphasizes the procedure in quest of knowledge actively while conducting the science experiment rather than the transfer of knowledge as the teacher's role is restricted to that of a facilitator who oversees and steers the experiment (Herranen & Aksela, 2019). Also, Limatahu and Prahani (2018) stated that, learning science has to be supported by science process skills for it to be more effective as it directly affect the students' academic achievement. Setiani, Surasmi and Tresnaningsih (2020) observed that science process skills when effectively use will help in the students' scientific literacy help them to develop their creativity, make them think like scientist and also perform better in their academic achievement.

Statement of the Problem

Biology is one of the science subjects that senior secondary school students offer in Nigeria. It is a very important science subject and a requirement for further learning of a number of science related professional courses like medicine, agriculture, pharmacy and others (Adesola, Olorode &

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Aranmolate, 2022). It is of great value in determining and shaping the future of the students and hence the future of the country in term of scientific, technological and economic development. However, despite its importance, the students' academic achievement in Biology has been consistently fluctuating for some time, which poses a serious problem that warrants investigation. Table 1 shows the results of students in Biology in Sokoto state from 2018-2023.

Table 1: Biology Students' Result of NECO in Sokoto State, Nigeria

Year	Total No of Student sat	No of students' with credit and above	No of students with fail	Percentage (%) Pass	Percentage (%) fail
2018	26982	11381	15601	42.18	57.82
2019	27841	11097	16744	39.86	60.14
2020	6552	4248	2304	64.84	35.16
2021	32974	16177	16797	49.06	50.94
2022	32254	20027	12227	62.09	37.91
2023	23042	12880	10152	55.09	44.1

Source: Exams Unit Ministry of Basic and Secondary Education Sokoto (MOBSES, 2024).

Table 1 shows the analysis of Biology students' achievement in the senior secondary school certificate examination from 2018-2023. The result shows fluctuation from 42.18% in 2018, 39.86% in 2019, 64.84% in 2020, 49.06% in 2021, 62.09% in 2022 and 55.09 in 2023. According to Widiyati and Sari (2019) this low academic achievement could be attributed to lack of science process skills and laboratory usage. This study investigated a correlational study of science process skills, laboratory utilization, self-efficacy and academic achievement among biology secondary school students in Sokoto state, Nigeria.

Objectives of the Study

The main objectives of this study are to:

1. Determine the relationship between science process skills and academic achievement in Biology among senior secondary school students in Sokoto, Nigeria.
2. Investigate the difference in the relationship of male and female biology students' science process skills and academic achievement in senior secondary school of Sokoto, Nigeria.

Research Questions

The study answered following research questions.

1. What is the relationship between science process skills and academic achievement in Biology among senior secondary school students in Sokoto, Nigeria?
2. What is the relationship between science process skills and academic achievement of male and female Biology students in senior secondary school Sokoto, Nigeria?

Research Hypotheses

The following research hypotheses were formulated and tested at 0.05 level of significance.

H^0_1: There is no significant relationship between science process skills and academic achievement in Biology among senior secondary school students in Sokoto, Nigeria.

H_{02}: There is no significant relationship between of male and female Biology students' science process skills and academic achievement in senior secondary school in Sokoto, Nigeria.

Research Methodology

Research design for the study was correlational research design, with population of 24,137 SS II Biology students which a sample of 379 students drawn using Krejcie and Morgan (1971) table for sample size determination. Multistage sampling technique was used to select the schools and

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participating students. Two instruments were used for data collection, namely; Science Process Skill Acquisition Test (SPSAT) and Biology Achievements Test (BAT). Instruments used were validated by 14 experts. The instruments achieved the reliability coefficients of 0.88 and 0.66 respectively. The data collected were analyzed using Descriptive (Mean, Standard Deviation and Pearson r) and Inferential (Simple Linear Regression and Multiple regressions) Statistics. The analyses of data were based on the research questions and stated null hypotheses of the study, all the hypotheses were tested at 0.05 level of significance.

Presentation of Results

The data analyses of the students' responses obtained and the result with respect to each research questions and hypotheses were presented in the following tables:

Research Question 1: What is the relationship between science process skills and the academic achievement in biology among senior secondary school students in Sokoto, Nigeria?

Table 2: Pearson (r) showing the Relationship Between Science Process Skill and Academic Achievement of Biology Students of Sokoto Secondary School.

Variable	N	$\bar{x}$	SD	r	Remark
Science Process Skill	379	7.82	7.36	0.361	Positive Weak Relationship
Biology Achievement Test	379	10.01	4.21		

Table 2 shows the relationship between science process skill and academic achievement of Biology students in secondary schools in Sokoto, Nigeria. From the Table, it is revealed that students mean score in science process skills vary widely ($\bar{x} = 7.82$, SD = 7.36), as shown by the high standard deviation, while their scores in the Biology achievement test ($\bar{x} = 10.01$, SD = 4.21) are more clustered and less dispersed, indicating more consistency in their academic achievement than in their science process skills. Furthermore, the Table revealed that there is a weak and positive relationship between the science process skill and the academic achievement of the students $r(379) = 0.361$. Figure 1 shows a scatter plot that depicts the nature of the relationship.

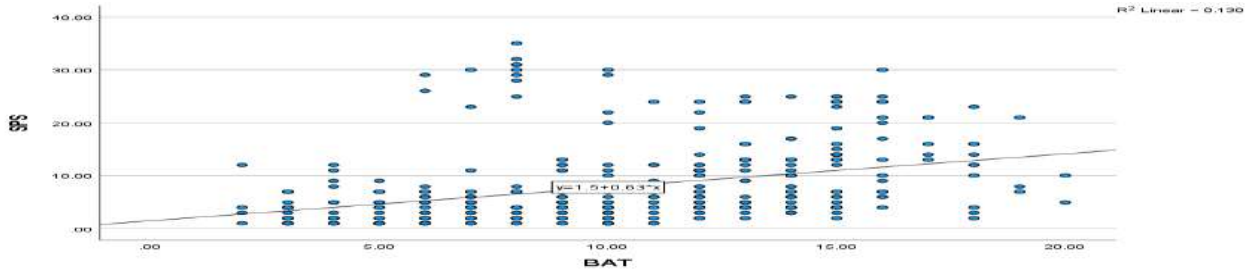


Figure 1: Scatter plot for the Relationship between Science Process Skill and Biology Achievement Test

The figure 1 shows a scatter plot illustrating the relationship between science process skills and Biology achievement test. The points show a weak upward trend, meaning that as students science process skills increase the Biology academic achievement tend to increases slightly. This is confirmed by the positive regression line, which indicates a small positive slope ($slope = 0.63$). The wide spread of the points around the line indicates weak relationship. The coefficient of determination $R^2 = 0.13$ means that only 13% of the variation in Biology achievement is explained by science process skills, while the remaining 87% is due to other factors.

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Null Hypothesis 1: There is no significant relationship between science process skills and the academic achievement in biology among senior secondary school students in Sokoto, Nigeria.

Table 2a: Model Summary for the Relationship Between Science Process Skills and Academic Achievement

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.361[a]	0.130	0.128	3.92669

a. Predictors: (Constant), SPS

Table 2a shows the regression model for the relationship between science process skill and academic achievement in Biology among senior secondary school students in Sokoto. The Table revealed that $R = 0.361$, a positive weak relationship between science process skills and academic achievement of the students, and $R^2 = 0.130$ meaning that the 13% of the students' academic achievement is explained by the science process skill. By implication, the science process skill has positive relationship with the student's academic achievement. However, the influence of the science process skill is weak as 13% academic achievement was explained only.

Table 2b: Regression Coefficients of Relationship between Science Process Skills and Academic Achievement of Biology Students

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	8.397	0.295		28.511	0.000
	SPS	0.206	0.027	0.361	7.516	0.000

Table 2b shows the regression coefficient of the relationship between science process skills and academic achievement of Biology students. The regression model implies that for every unit increase in science process skills there is a corresponding of 0.206 increase in the academic achievement of the students in Biology. The constant 8.397 unit increase account for other factors associated with the Biology academic achievement. The null hypothesis that stated "There is no significant relationship between science process skills and the academic achievement in Biology among senior secondary school students in Sokoto, Nigeria" is hereby rejected having ($p = 0.000$). Thus, science process skill is influence academic achievement of the Biology students.

Research Question 2: What is the relationship between science process skills and academic achievement of male and female biology students in senior secondary school Sokoto, Nigeria?

Table 3: Pearson (r) showing the Relationship Between Science Process Skills and Academic Achievement of Male and Female Biology Students of Sokoto Secondary School.

Gender	Variables	N	$\bar{x}$	SD	r	Remark
Male	Science Process Skill		9.28	6.83	0.528	Moderate and Positive Relationship
	Biology Achievement Test	171	11.09	4.48		
Female	Science Process Skill		6.63	7.58	0.168	Weak and Positive Relationship
	Biology Achievement Test	208	9.12	3.74		

Table 3 shows the relationship between science process skill and academic achievement score of male and female secondary school students in Biology. The Table provided that male students' mean in science process skills vary widely ($\bar{x} = 9.28$, SD = 6.83), as shown by the high standard deviation,

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while in the Biology achievement test ($\bar{x} = 11.09$, SD = 4.48), the scores are more close to the mean and less dispersed, indicating more uniformity in academic achievement than in science process skills. Furthermore, the Table revealed that there is moderate and positive relationship between the male students' science process skill and academic achievement $r(171) = 0.528$. Figure 4.4aillustrate the nature of the relationship. Again, the Table 20 indicated wide variation in female students' mean scores in science process skills ($\bar{x} = 6.63$, SD = 7.58), the standard deviation is higher than the mean, while in the Biology achievement test ($\bar{x} = 9.12$, SD = 3.74), indicating less dispersed in the females' mean scores in the academic achievement revealing uniformity in the academic achievement than in science process skills of the female students. Furthermore, the Table revealed that there is moderate and positive relationship between the male students' science process skill and academic achievement $r(208) = 0.168$. Figure 5 shows a scatter plot that illustrate the nature of the relationship.

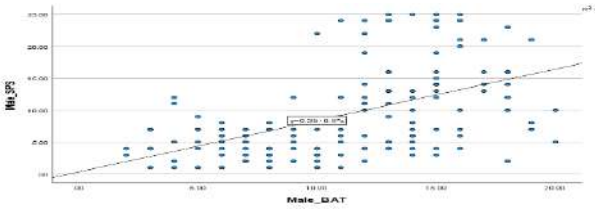


Figure a

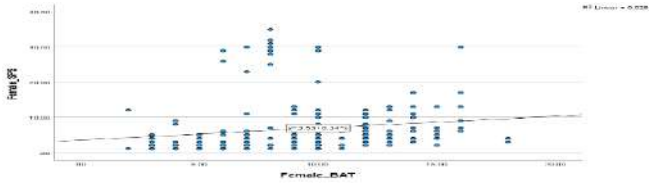


Figure b

Figure 3a & b: Scatter plot of Male and Female Students' Relationship of Science Process Skills and Academic Achievement in Biology

Figure 3a shows the relationship between male academic achievement in Biology and their science process skill. The figure indicated that the scatter plot is positive upward trend, meaning that as male students' science process skills increase their Biology academic achievement also increases. The regression equation $y = 0.35 + 0.81x$ indicates a strong positive slope, showing that for every one-unit increase in the male science process skills their academic achievement increases by 0.81 units. This indicates a strong relationship between the male academic achievement and their science process skills. On the other hand, Figure 3b shows the relationship between female academic achievement and their science process skills. The figure shows that the dots are widely scattered with a slight upward trend, showing that as female students' academic achievement increases, their science process skills tend to increase marginally. The regression equation $y = 5.53 + 0.34x$ shows a very small positive slope (0.34), meaning the increase in science process skill for each unit increase in the academic achievement is minimal. In summary, there is moderate, positive and meaningful relationship between science process skill and academic achievement of male Biology students, while for female students the relationship is very weak and positive. This shows that the male science process skills contribute significantly to their academic achievement, while the female science process skill gives little contribution to their academic achievement.

Hypothesis 2: There is no significant relationship between science process skills and academic achievement of male and female Biology students in senior secondary school Sokoto, Nigeria.

Table 3a: Regression Model of the Relationship between Science Process Skills and Academic Achievement of Male and Female Biology Students

Gender	Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Male	1	0.528	0.279	0.274	3.81712
Female	1	0.168	0.028	0.023	3.69968

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Table 3a shows the regression model of the relationship between science process skills and academic achievement of male and female Biology students. For the male students, $R = 0.528$ indicating a strong influence of the male science process skill on their academic achievement, while $R^2 = 0.279$ revealing that 27.9% of the variation in the male students' academic achievement is explained by their science process skills, this shows a moderate positive relationship.

Again, Table 3a shows that $R = 0.168$ revealing weak relationship between science process skill and academic achievement of female students, while $R^2 = 0.028$ showing that 2.8% of the variation in female students' academic achievement is explained by their science process skills, this confirmed a very weak positive relationship between female students' science process skill and their academic achievement.

Table 3b Regression Coefficients of the Relationship between Science Process Skills and Academic Achievement of Male and Female Biology Students

Gender	Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
			B	Std. Error	Beta		
Male	1	(Constant)	7.886	.493		15.982	0.000
		SPS	0.347	0.043	0.528	8.079	0.000
Female	1	(Constant)	8.567	0.341		25.118	0.000
		SPS	0.083	0.034	0.168	2.441	0.015

Dependent Variable: BAT of Male and Female

Table 3b shows the regression coefficient for male and female Biology students' science process skill and academic achievement. For the male students the regression coefficient is $Y = 7.886 + 0.347x_1$, this means for every unit increase in science process skill (x_1) of the male students there is corresponding of 0.347 unit in their academic achievement, while constant factors contribute by 7.886-unit increase.

On other hand, for the female students the regression coefficient is $Y = 8.567 + 0.083x_2$, revealing that for every -unit increase in the female students' science process skill there is also 0.083unit increase in their academic achievement, however the increase is minimal. 8.567-unit increase in the constant factors also influences the female students' academic achievement. In summary, the regression analysis showed that the relationship between science process skills and academic achievement was statistically significant for both male and female Biology students. For the male students, the regression coefficient was significant at $p = 0.00$, while for the female students, it was likewise significant at $p = 0.015$. Since both p-values are lower than 0.05 level of significance, this indicates that science process skills significantly predict academic achievement for both male and female students. Thus, the hypothesis that stated "There is no significant relationship between science process skills and academic achievement of male and female Biology students in senior secondary schools in Sokoto, Nigeria" is hereby rejected. By implication, the strength of the relationship differs, with male students showing a stronger predictive relationship than female students. The statistical evidence confirms that science process skills contribute meaningfully to academic achievement in both male and female students.

Discussion of Findings

The findings from research question one shows a positive weak relationship between science process skills and the academic achievement in biology among senior secondary school students in Sokoto, Nigeria. This finding is in line with the findings Adebayo et al. (2022) reported that students with stronger science process skills demonstrated better academic performance in various science subjects, including biology, suggesting that proficiency in skills such as observation,

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experimentation, and data analysis can enhance comprehension and problem-solving abilities in science. The study contradicted the findings of Eze (2023), while science process skills are important, the extent of their impact on academic performance in biology could be limited if not paired with effective teaching strategies and a conducive learning environment.

The findings of hypothesis one shows a significant relationship between science process skills and the academic achievement in biology among senior secondary school students in Sokoto, Nigeria. The finding added that only 13% of the variation in science process skills is explained by Biology achievement, while the remaining 87% is due to other factors. Meaning that as Biology achievement increases, the students science process skills also tend to increases slightly. The finding of this study is in line with Emmanuel, Comfort, and Venita (2018); Saputro, Irwanto, Atun and Wilujeng (2019); Ardina, Rizhal, Diana and Mieke (2020); Ibrahim, Mohd and Hairul (2023); Libata, Ali and Ismail (2023); Carlo Jaime, (2023), were of the opinion that science process skills has significant difference on academic achievement as their result revealed positive and significant correlation between science process skills and academic achievement. They also agreed that science process skill is one of the important skills possessed by students in conducting the learning process, that if students have good science process skills, they will be able to more easily understand learning concepts.

The findings from research question two shows there is moderate, positive relationship between science process skill and academic achievement of male students, while for female students' shows very weak and positive relationships among Biology Secondary School Students in Sokoto State this attributed to differences in classroom participation, confidence in practical activities, exposure to laboratory experiences, cultural expectations, teacher encouragement, and access to science learning resources. Male students are often more actively engaged in experimental and inquiry-based learning, which strengthens the connection between science process skills and academic performance, while female students may experience lower self-efficacy, limited participation in practical work, anxiety toward science-related tasks, or socio-cultural barriers that weaken the relationship despite still showing a positive trend. This finding is in agreement with the study of Akinbobola and Afolabi (2022), who reported that male students demonstrated a stronger relationship between science process skills and academic achievement in biology, attributing this to higher participation and confidence during practical activities. Similarly, Sani and Mohammed (2023) found a moderate positive relationship between science process skills and biology achievement among male secondary school students in North-West Nigeria, noting that male students tend to engage more actively in hands-on laboratory and inquiry-based tasks, which enhances their academic performance. However, the findings contradicted the study of Okeke and Eze (2022), who found no significant gender difference in the relationship between science process skills and biology achievement, concluding that both male and female students benefited equally when exposed to learner-centred and activity-based instructional strategies.

The findings from hypothesis two shows there is significant relationship between science process skills and academic achievement of male and female Biology students in senior secondary school Sokoto, Nigeria. This showed that the male science process skills contribute significantly to their academic achievement, while the female science process skill gives little contribution to their academic achievement. The finding of this study is in line with Kasinatham, (2023) who found out that there are gender differences in favour of male students in science process skills and academic achievement. In contrast to findings favoring male students, some studies have documented stronger relationships among female students. Achor and Kurumeh (2020); Ogunniyi and Fakayode (2023)

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found that female students exhibited higher proficiency in certain science process skills such as observation, classification, and inference, which translated into better academic performance in Biology. Further contradictory evidence was provided by Okoli and Okeke (2019); Ogunleye and Babajide (2021); Ezeudu and Ezinwa (2022) found that science process skills significantly predicted academic achievement for both male and female students without any statistically meaningful difference between genders.

Conclusion

Based on the findings of this study it was therefore concluded that:

1. There is a positive but weak relationship between the science process skill and the academic achievement in biology among senior secondary school students in Sokoto, Nigeria.
2. Male science process skills has moderate, positive and significant relationship to their academic achievement, while the female science process skills has weak, positive and significant relationship with their academic achievement.

Recommendation

On the basis of the findings reported above, the following recommendations were made:

1. Biology teachers should deliberately integrate the teaching of science process skills, such as observing, measurement, classifying, predicting and experimenting, into everyday lessons.
2. The sokoto state ministry of education should provide a Teacher training programmes and workshops that will give particular attention to strategies that help female students derive greater benefit from science process skills.

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Trends on Sociological Effects of Insecurity on Internally Displaced Persons Educational Development in Northern Nigeria: A PRISMA-Based Systematic Literature Review

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Abstracts

Insecurity is a major challenge to the educational development and social well-being of internally displaced persons (IDPs) in Northern Nigeria. This study reviewed empirical evidence on its sociological effects on access to education, school participation, continuity of learning and educational outcomes. Adopting the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, a total of 13 peer reviewed empirical studies published between 2017 and 2026 were identified, screened, and reviewed across various databases. The findings show that insecurity disrupts schooling, limits access to education, destroys schools, displaces learners, reduces teacher availability and worsens learning conditions. It also contributes to psychological distress, poverty, child labour, early marriage and social exclusion, all of which hinder educational participation. Displacement further weakens family and community support systems. Although government, humanitarian and community interventions have improved access in some areas, they remain insufficient. The study concludes that the educational challenges of IDPs are rooted not only in damaged infrastructure but also in the broader social and economic effects of insecurity. It recommends improved security, inclusive policies, psychosocial support, adequate funding, teacher deployment and stronger collaboration among stakeholders. The study also identifies research gaps and suggests directions for future empirical investigations.

Keywords: *I*nsecurity, internally displaced persons, educational development, sociological effects

Introduction

Insecurity has emerged as a major sociological challenge to educational development and the social well-being of internally displaced persons (IDPs) in Northern Nigeria. Armed conflict, banditry, insurgency, kidnapping, communal violence and other forms of insecurity have generated displacement and disrupted the social conditions necessary for continuous education. The consequences extend beyond the physical destruction of schools; insecurity also affects social relationships, psychological well-being, participation, educational access, institutional support and the continuity of learning. Recent evidence from Northern Nigeria similarly shows that insecurity has displaced communities, weakened social cohesion and hindered access to education and other essential services (Oxford Policy Management/Cloneshouse, 2025).

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The reviewed studies demonstrate that displacement is one of the most immediate sociological effects of insecurity on education. Displaced children frequently lose access to their former schools and may experience prolonged interruption of learning, restricted educational opportunities and difficulties adapting to new environments (Abduljabbar & Dauda, 2022; Ezera & Oghenede, 2021). In IDP camps, these challenges are compounded by inadequate infrastructure, insufficient resources, shortages of qualified teachers and weak institutional support (Ogunode et al., 2022; Sadat et al., 2021). Consequently, education for displaced children becomes fragmented and vulnerable to prolonged interruption, thereby increasing the risk of educational exclusion and the emergence of a generation with limited educational opportunities. The reviewed literature further indicates that insecurity produces important social and psychological effects that directly influence educational participation. Fear, trauma, poverty, social exclusion and displacement reduce school attendance and participation, while school closures and teacher shortages disrupt the continuity of learning (Oxford Policy Management/Cloneshouse, 2025). Among students and teachers, insecurity has also been associated with reduced motivation, diminished interaction and weakened confidence. For example, Sheu and Sule (2025) found that insecurity reduced instructional time, student engagement and teacher motivation in the Gusau Educational Zone of Zamfara State. Similarly, Bashir and Abubakar (2025) reported that insecurity negatively affected affection, confidence, trust and interpersonal relationships among secondary school students in Maru, Zamfara State. These findings suggest that the sociological consequences of insecurity extend beyond access to school to the quality of relationships and social interactions through which learning takes place.

The literature also reveals significant inequalities in the educational experiences of displaced populations. Insecurity disproportionately affects vulnerable groups, including children, girls and persons with disabilities, while displacement creates fragmented learning trajectories and increases the risk of dropout, child labour and early marriage (Oxford Policy Management/Cloneshouse, 2025). Furthermore, insufficient funding, insecurity and institutional weaknesses continue to limit efforts by governmental and non-governmental organisations to provide sustainable educational opportunities for IDPs (Tanimu et al., 2026). Thus, although education is expected to provide protection, social integration, resilience and opportunities for future development, insecurity often weakens these functions by creating conditions of poverty, exclusion, trauma and educational disadvantage. The evidence also suggests that the effects of insecurity are not confined to the immediate disruption of schooling but may have long-term implications for the educational development and social integration of IDPs. Children who experience displacement and traumatic events may require psychological, emotional, financial and educational support to adapt to new environments (Abubakar et al., 2020). Similarly, inadequate coordination, financial constraints and weak humanitarian support can reduce the effectiveness of interventions designed to assist displaced populations (Oderinde, 2026). The emerging evidence therefore indicates that educational development among IDPs is influenced by the interaction of insecurity with social displacement, poverty, institutional capacity, humanitarian assistance, school resources and community support. Despite the growing body of literature on insecurity and education in Northern Nigeria, existing studies remain fragmented across different locations, populations and dimensions of educational development. Some studies focus primarily on access and enrolment, while others examine school closures, teacher motivation, interpersonal relationships, infrastructure or humanitarian support. There is therefore a need to synthesise the existing evidence systematically in order to establish the broader trend in the sociological effects of insecurity on the educational development of IDPs in Northern Nigeria. Such a synthesis is important for identifying recurring patterns, methodological

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trends, geographical concentrations and major sociological outcomes reported in the literature. Accordingly, this study reviews existing evidence to examine how insecurity has affected educational access, participation, continuity, social relationships, psychological well-being, institutional support and the broader educational development of internally displaced persons in Northern Nigeria.

Research Methodology

This study adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to guide the selection and evaluation of literature for the systematic review. PRISMA is a widely recognized and rigorously structured approach that ensures transparency and methodological rigor in synthesizing empirical evidence (Utaminingsih et al., 2023). By systematically gathering and analyzing data from multiple studies, sociological effect of insecurity on educational access, participation, continuity of learning and education conditions of internally displaced persons (IDPs) in Northern Nigeria. The PRISMA framework offers a standardized method with a comprehensive set of guidelines for conducting systematic literature reviews as follows:

Research Questions

1. What are the sociological effects of insecurity on educational access and participation among internally displaced persons (IDPs) in Northern Nigeria?
2. How does insecurity affect the continuity of learning and the educational conditions of internally displaced persons (IDPs) in Northern Nigeria?
3. What effects does insecurity have on the educational outcomes and overall educational development of internally displaced persons (IDPs) in Northern Nigeria?

Search Strategy

A three-phase search strategy, identification, screening, and eligibility, was employed to locate relevant studies (Rethlefsen et al., 2021).

1. **Identification Phase:** Comprehensive keyword searches were conducted across multiple databases (ERIC, Google Scholar, Journal Storage (JSTOR), Semantic Scholar, OpenSource, and SpringerLink) to identify peer-reviewed empirical studies published between 2017 and 2026. Boolean combinations included: "Insecurity" AND "Educational development"; (educational access OR participation OR continuity OR conditions) AND "Internally displaced persons" AND "Northern Nigeria" The initial search yielded 253 records.
2. **Screening Phase:** Duplicate records (123) were removed, leaving 130 articles for title and abstract screening. Studies unrelated to sociological effect of insecurity on IDPs were excluded, reducing the pool to 13 full-text articles.
3. **Eligibility:** This table streamlines the eligibility process while maintaining all essential criteria for transparency and reproducibility. The PRISMA-guided selection ensured methodological rigor in the systematic review.

Table 1: Eligibility Criteria for selection of the articles

Category	Inclusive Criteria	Exclusive Criteria
Population	IDPs educators and IDPs providers	Not on students' academic achievement/performance
Intervention	Studies investigating on insecurity challenges	Studies not focused on insecurity challenges

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Outcomes	Educational access, participation, continuity and conditions	No empirical assessment of these outcomes
Research design	Qualitative, Quantitative and Mixed-method design	Experimental and quasi-experimental
Publication	Peer-reviewed articles in English (2017-2026)	Dissertations, non-peer-reviewed articles, or studies outside the date range
Geographical Scope	Northern, Nigeria	Global studies

Data Extraction and Analysis

Relevant data were extracted from each study, including author (s), year, title, research design, country, sociological effect, and key outcomes. Findings were narratively synthesized and compared across contexts. The summary report of the selected articles is presented in Table 1. The findings of the review are presented following the sequences, such as the name of the authors, publication years, titles, research design, country and reported sociological effect of insecurity on IDP

Table 2: Data Extraction and Analysis

S/N	Authors & year	Location	Population	Method	Sociological Effects of Insecurity	Major findings relevant to the review
1	Abduljabbar & Dauda (2022)	Nigeria, with emphasis on conflict-affected North-west and North-East	Secondary Sources and discussion of IDP children in emergency context	Analytical /conceptual review	Displacement, poverty, insecurity , school disruption, inadequate teachers and infrastructure	Conflict, banditry insurgency and other emergencies interrupt children's education and create shortage of teachers, teaching materials and basic infrastructure. The author argue that education in emergencies is necessary for social reconstruction, national development and the reintegration of affected children.
2	Ezera & Oghenede (2021)	Nigeria; IDP camp context	Internally Displaced children/IDP educational context	Analytical /conceptual review	Displacement and restricted educational opportunities	Many children in internally displaced persons' camps grow up without schooling and miss out on the protection and support that education can provide, largely

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						because conflicts and disasters often persist for years or even decades. While the international community has encouraged non-formal learning at the primary level, education remains vital for children who have been suddenly displaced.
3	Ogunode, Chijindu, & Jegede (2022)	Nigeria, IDP camps	IDP education services and education providers	Mixed-methods approach; desk review, survey, and FGDs	Inadequate infrastructure, insufficient resources, teacher shortages and displacement-related educational disadvantage	The paper concludes that inadequate funding, shortage of specialized and professional teachers, lack of modern infrastructural facilities, inadequate instructional materials, lack of data, corruption, poverty, limited school facilities and instructional challenges of internally displaced person (IDP) were the problems hindering the provision of education services for the Internally Displaced Persons (children) in IDPs camps in Nigeria.
4	Sadat, Jaafar, Rosnon, Khir (2021)	Borno State, North-East Nigeria	NGO and IDP camp context	qualitative research design	Displacement, inadequate hummanitarian support and institutional challenges	The study indicate that, One of the most serious setback to educational development in Nigeria is non availability of data or lack of authenticity where available (National Policy on Education, 1979). Educational planners all over developed economics of the world, set future educational targets based on objective identification of the

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						people"s aspirations, problems, needs and gaps in the field of education.
5	Sheu & Sule (2025)	Gusau Educational Zone, Zamfara State	156 Civic education teachers; sample of 108 teachers	Survey design, multistage sampling; structured questionnaire; Cronbach's alpha= .83	Fear, reduced teacher motivation, reduced student participation and disruption of teacher-student interaction	Insecurity reduced instructional time, student engagement and teacher motivation. It also delayed examinations, limited assessment practices and reduced teachers' confidence in evaluating students. These effects threaten curriculum coverage and educational quality.
6	Bashir & Abubakar (2025)	Maru, Zamfara State	1,784 secondary school students; sample: 100 students	Descriptive survey; purposive sampling; structured questionnaire; Cronbach's alpha	Reduced affection, confidence, interaction and trust among students	Insecurity negatively affected students' interpersonal relationships. The disruption of affection, confidence and interaction is sociologically important because positive relationships support cooperation, peer learning, help-seeking and effective participation in educational activities
7	Oxford Policy Management/ Cloneshouse (2025)	Nine LGAs across Katsina, Zamfara and Niger States	Learners, teachers, parents, community leaders and education stakeholders	Mixed-methods approach; desk review, survey, KIIs and FGDs	Fear, trauma, displacement, poverty, school closures droupout, child labour, early marriage, teacher shortages and social exclusion	Insecurity resulted in school closures, reduced attendance, learning disruption, trauma, weakened concentration, teacher shortages and educational disengagement. Displacement overburdened host schools and created fragmented learning trajectories. The study also found particular vulnerability among girls and persons with disabilities

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8	Oderinde (2026)	North-East Nigeria	Secondary sources, including journals, reports, books, theses and newspaper	Qualitative approach based on secondary data	Limited access, social vulnerability, displacement and inadequate educational support	The study revealed that IDPs is affected by many factors such as land crisis, armed violence, herders-farmers conflict, banditry, and communal violence. Organizations such as UNHCR have attempted to provide support, financial shortfalls and mismanagement have greatly reduced the impact of aid, leaving many displaced people vulnerable and lacking basic assistance. The study therefore concludes that both government and non-governmental bodies must take a more proactive role in fostering peace and improving the coordination of aid to support the recovery and reintegration of IDPs in the region.
9	Tanimu et'al., (2026)	Borno State Nigeria	A total population of 135 was sampled, with a sample size of 48 respondents	mixed research approach,	Access to education	Despite the efforts made by the Nigerian government and other non-governmental organizations in creating opportunities and supporting internally displaced persons in accessing education, the study established that these efforts are not enough, particularly due to funding, security, and funding issues.
10	Abubakar S. et'al., (2020)	North-Eastern Nigeria	Secondary sources, including journals, reports, books, theses	Qualitative approach based on secondary data	Access to education	There is evidence that some of the children with traumatic experience are likely going to develop a form of mental disorder or

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			and newspaper			may have a problem to settle in a new environment. They, therefore, would benefit from psychological, emotional, financial, educational and medical support which will enable them to settle in their new environment.
11	Samuel W. A & Akorvictor O., (2018)	Nigeria	Secondary sources, including journals, reports, books, theses and newspaper	Qualitative approach based on secondary data	Curriculum design	The study conclude that natural disaster like health plagues, food shortage, drought, earthquakes may not easily be tackled because they may not have power over them but their effects could be mitigated and reduced to the barest minimum if proper mechanisms of education through a well-designed and suitable curriculum is constructed to fit in and used to fight the challenge of insecurity and the internal displacement of people even though a tailor made curriculum could not be put in place because of the multifaceted of insecurity and the nature of what caused the internal displacement of people
12	John Y. A., Christopher S. O., & Jacob G. A., (2020)	North central Nigeria	Questionnaires designed were administered on one hundred and sixty (160) respondents	Survey Research Design	negatively affected student's enrolment	This study revealed that IDPs can be effectively integrated into the wider society. This approach or effort stemmed from the hope that by providing a formidable advocacy, incidences of diversion

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						of supplies to IDPs can be checkmated.
13	Glory E. B. & Joseph O. E., (2026)	Nigeria	Secondary journal articles, government reports and institutional publications	qualitative approach based	Negatively affected school attendance, destroyed educational infrastructure, displaced learners and teachers.	The study argues that insecurity has transformed many schools into unsafe spaces, thereby discouraging enrollment and increasing dropout rates, especially among children in vulnerable communities. The paper further examines government interventions such as military operations, the Safe School Initiative, and collaboration with international organizations aimed at improving school safety and educational continuity.

Research Question One: What are the sociological effects of insecurity on educational access and participation among internally displaced persons (IDPs) in Northern Nigeria?

The reviewed evidence indicates that insecurity significantly restricts educational access and participation among IDPs through displacement, school closures, fear, poverty, insecurity-related trauma and inadequate educational support. Abduljabbar and Dauda (2022) reported that conflict, banditry, insurgency and other emergencies disrupt children's education by causing displacement and creating shortages of teachers, instructional materials and basic infrastructure. Similarly, Ezera and Oghenede (2021) found that many children in IDP camps grow up without regular schooling because prolonged conflicts and disasters restrict their educational opportunities. The evidence further indicates that displacement often creates fragmented educational trajectories. The Oxford Policy Management/Cloneshouse (2025) study, covering nine Local Government Areas across Katsina, Zamfara and Niger States, found that insecurity resulted in school closures, reduced attendance, displacement, poverty, dropout, child labour, early marriage and social exclusion. These conditions particularly affected girls and persons with disabilities. Thus, insecurity does not merely prevent IDPs from enrolling in school; it also reduces their ability to participate regularly and meaningfully in educational activities.

However, the reviewed studies also show that the availability of educational opportunities does not necessarily guarantee effective access. Tanimu et al. (2026) established that government and non-governmental efforts to support IDPs were insufficient, particularly because of funding, security and financial challenges. Similarly, Oderinde (2026) found that displaced persons in North-Eastern Nigeria faced limited access because of armed violence, banditry, farmer-herder conflicts, communal

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violence and inadequate humanitarian support. Although organisations attempted to provide assistance, funding shortfalls and poor coordination reduced the effectiveness of interventions. At the interpersonal and sociological level, Bashir and Abubakar (2025) found that insecurity reduced affection, confidence, interaction and trust among students. These conditions negatively influence peer relationships, cooperation, help-seeking and participation in educational activities. The findings therefore suggest that educational access should be understood not only as physical entry into school but also as the ability to participate in a safe, supportive and socially functional learning environment.

Finally, the evidence demonstrates that insecurity restricts educational access and participation through displacement, school closures, poverty, fear, trauma, dropout, child labour, early marriage, social exclusion, insufficient educational support and weakened interpersonal relationships. These effects are particularly severe among vulnerable groups such as girls, children with disabilities and displaced children living in unstable conditions.

Research Question Two: How does insecurity affect the continuity of learning and the educational conditions of internally displaced persons (IDPs) in Northern Nigeria?

The reviewed studies reveal that insecurity severely disrupts the continuity of learning by causing school closures, displacement of learners and teachers, interruption of instructional time and inadequate provision of educational resources. Sheu and Sule (2025), in their study of civic education teachers in Gusau Educational Zone, Zamfara State, found that insecurity reduced instructional time, student engagement and teacher motivation. It also delayed examinations, limited assessment practices and reduced teachers' confidence in evaluating students. These disruptions threatened curriculum coverage and the quality of education. Similarly, the Oxford Policy Management/Cloneshouse (2025) study found that insecurity created fragmented learning trajectories as schools were closed and displaced learners experienced repeated interruptions in their education. The displacement of learners and teachers further weakened the continuity of teaching and learning. This suggests that insecurity may produce educational discontinuity even where alternative educational arrangements are available because learners frequently move between locations or experience prolonged periods without formal schooling.

The educational conditions of IDPs are further affected by inadequate infrastructure, shortages of teachers, insufficient instructional materials and inadequate funding. Ogunode, Chijindu and Jegede (2022) identified inadequate infrastructure, insufficient resources, teacher shortages, inadequate funding and the lack of modern instructional materials as major barriers to the provision of education in IDP camps. The study also identified poverty, corruption, limited school facilities and the shortage of specialised and professional teachers as factors hindering the provision of effective education to displaced children. Sadat, Jaafar, Rosnon and Khir (2021) similarly highlighted displacement, inadequate humanitarian support and institutional challenges in the educational environment of IDPs. The study emphasized the importance of reliable data and accurate identification of educational needs for effective educational planning. Without accurate information about displaced populations, educational planners may be unable to determine the number of learners, teachers, facilities and resources required.

The reviewed literature also indicates that insecurity produces psychological and emotional conditions that interfere with learning continuity. Abubakar et al. (2020) observed that children who

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experience traumatic events may develop psychological and emotional difficulties and may struggle to adjust to new environments. Such children require psychological, emotional, financial, educational and medical support to settle into their new environments. Samuel and Akorvictor (2018) further argued that appropriate curriculum design and educational mechanisms are needed to mitigate the effects of insecurity, natural disasters and internal displacement. Overall, the evidence shows that insecurity interrupts learning through school closures, displacement, teacher shortages, reduced instructional time, delayed examinations, inadequate assessment, insufficient funding, inadequate infrastructure and shortages of instructional materials. In addition, trauma and psychological difficulties reduce learners' capacity to adjust to new educational environments. Consequently, insecurity produces discontinuous and unstable learning experiences for IDPs.

Research Question Three: What effects does insecurity have on the educational outcomes and overall educational development of internally displaced persons (IDPs) in Northern Nigeria?

The findings from the reviewed studies indicate that insecurity negatively affects educational outcomes and the broader educational development of IDPs. One major effect is educational disengagement, which may manifest through poor attendance, dropout, reduced participation and limited commitment to learning. The Oxford Policy Management/Cloneshouse (2025) study associated insecurity with reduced attendance, dropout, child labour, early marriage and educational disengagement. These outcomes reduce the likelihood that displaced learners will complete their education and acquire the knowledge and skills necessary for personal and national development. Insecurity also weakens the quality of educational delivery. Sheu and Sule (2025) found that fear, reduced teacher motivation, limited student participation and disruptions in teacher–student interaction affected instructional processes. The delay of examinations and limitations in assessment practices further affected the ability of teachers and schools to monitor learners' progress. When curriculum coverage is reduced and assessment systems are disrupted, students may experience learning gaps and weaker educational achievement.

The evidence further suggests that poor educational outcomes are associated with inadequate educational resources and institutional weaknesses. Ogunode et al. (2022) identified inadequate funding, shortages of professional teachers, inadequate infrastructure and insufficient instructional materials as major challenges affecting education in IDP camps. These conditions limit the quality of learning experiences and reduce the capacity of educational institutions to support the development of displaced learners. The psychological and sociological consequences of insecurity also have implications for educational development. Bashir and Abubakar (2025) found that insecurity negatively affected affection, confidence, interaction and trust among students. Since these social relationships support cooperation, peer learning, help-seeking and participation, their disruption may indirectly affect students' educational development. Likewise, Abubakar et al. (2020) reported that children exposed to traumatic experiences may experience psychological and emotional difficulties that affect their adjustment to new environments.

At the broader societal level, the reviewed studies suggest that insecurity undermines the role of education in social reconstruction and national development. Abduljabbar and Dauda (2022) argued that education during emergencies is important for social reconstruction, national development and the reintegration of affected children. However, when insecurity prevents children from accessing education, it can perpetuate poverty, social exclusion and vulnerability. Tanimu et al. (2026) also demonstrated that insufficient funding, security problems and inadequate support systems limit the

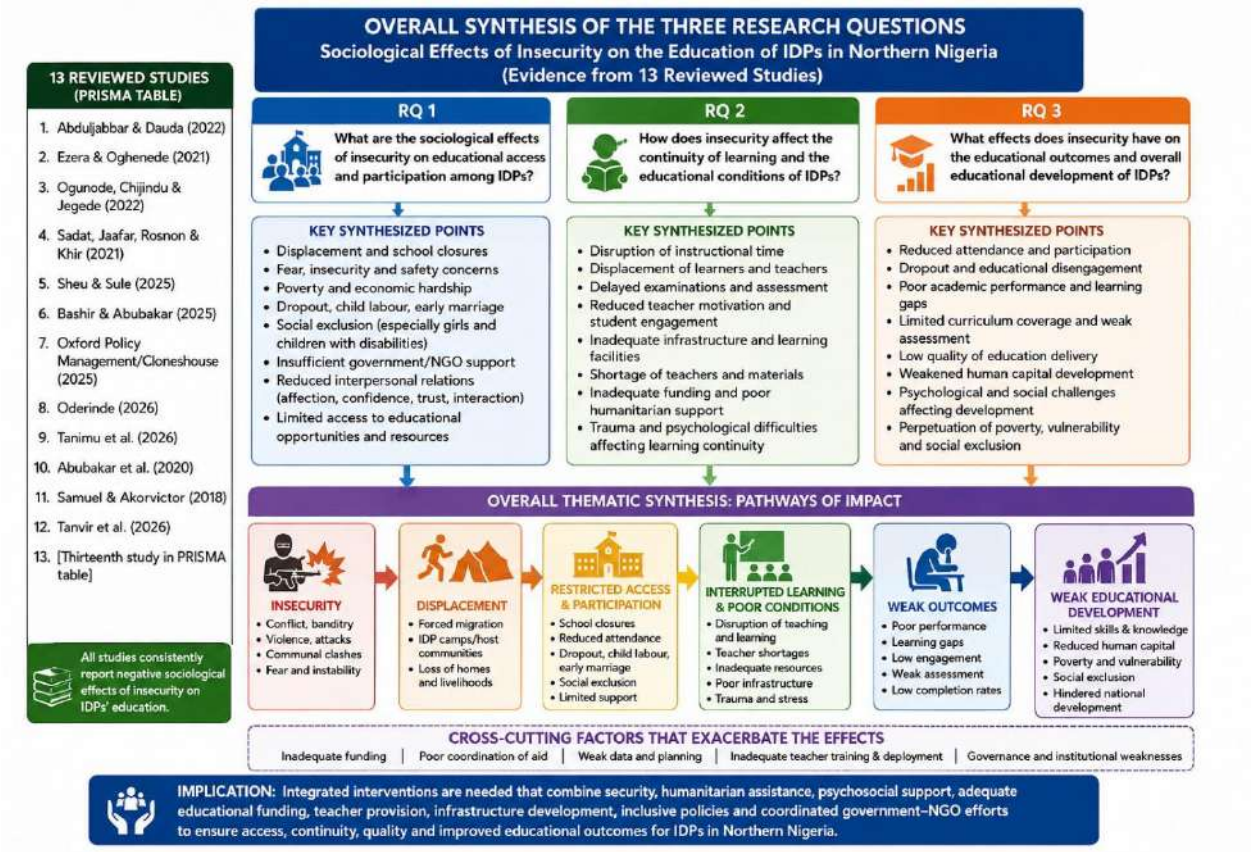
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effectiveness of interventions designed to improve educational access for IDPs. Therefore, insecurity negatively affects educational outcomes by increasing absenteeism, dropout, educational disengagement and learning disruption while reducing student participation, teacher motivation, curriculum coverage and the quality of assessment. At the level of educational development, insecurity contributes to learning gaps, poverty, social exclusion and weakened human capital development. Therefore, the educational consequences of insecurity extend beyond individual learners to the broader prospects of social reconstruction and national development.

Overall Synthesis

The synthesis of the reviewed studies demonstrates that insecurity has a cumulative and interconnected effect on the education of IDPs in Northern Nigeria. The effects can be summarised in diagram as follows:



Researcher (2026)

The evidence also shows that the effects are mutually reinforcing. For example, insecurity may cause displacement, while displacement creates poverty and unstable living conditions. These conditions can lead to school absence, dropout, child labor and early marriage. At the same time, inadequate funding, teacher shortages, poor infrastructure and insufficient instructional materials reduce the capacity of schools and humanitarian organizations to provide effective educational services. Trauma and weakened interpersonal relationships further reduce students' ability to participate fully in learning. Therefore, the reviewed evidence suggests that the sociological effects of insecurity on IDP education are not limited to the physical destruction or closure of schools. They include displacement, social exclusion, poverty, trauma, weakened social relationships, reduced

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participation, educational discontinuity, teacher shortages, inadequate resources, dropout and diminished educational development. The findings support the need for integrated interventions that combine security, humanitarian assistance, psychosocial support, adequate educational funding, teacher provision, infrastructure development and coordinated government and non-governmental support for IDPs.

Recommendation

The evidence from the 13 reviewed studies demonstrates that insecurity requires a multidimensional educational response. Consequently, interventions should not focus solely on school construction or the provision of learning materials. A comprehensive response should simultaneously address security, displacement, poverty, trauma, teacher shortages, inadequate infrastructure, weak coordination, poor funding and social exclusion. An integrated approach involving government, NGOs, communities, security agencies and educational institutions is therefore essential for ensuring educational access, continuity, participation, quality and sustainable educational development among IDPs in Northern Nigeria.

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Impact Of Artificial Intelligence-Based Fitness Applications On Physical Activity Participation And Health Behaviour Among Undergraduate Students In Federal Universities In North-West Nigeria

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Abstract

The aim of this study was to determine the effect of Artificial Intelligence (AI) based fitness applications on physical activity participation and health behaviour among the undergraduates of Federal Universities, North-West Nigeria. The four objectives, four research questions, and four null hypotheses were the compass of this study. For the study, a descriptive correlational survey research design was used. The population consisted of undergraduate students of a few Federal Universities in the Northwest Nigeria. 384 undergraduate students were chosen as respondents using a multistage sampling technique. The Artificial Intelligence Fitness Applications, Physical Activity and Health Behaviour Questionnaire (AIFAPHBQ) was used to gather data. The internal consistency of the instrument was evaluated by Cronbach's Alpha reliability technique and the overall reliability coefficient obtained was 0.84. It was endorsed by experts in the field of Physical and Health Education, Educational Technology, and Measurement and Evaluation. The mean and the standard deviation were used to solve the problems in the study, while the independent-samples t-test and Pearson Product Moment Correlation were applied to test the null hypotheses at 0.05 level of significance. Based on the results, the use of AI-based fitness apps among undergraduate students was at moderate level (Grand Mean = 2.84, SD = 0.76). Use of the AI fitness app was positively associated with physical activity participation ($r = .61$, $p < .001$) and health behaviour ($r = .58$, $p < .001$). The results also revealed that male students felt they were using AI based fitness apps slightly more than female students, but this was not statistically significant ($t = 1.63$, $p = .104$). The researchers found that there is significant potential for the use of AI fitness apps to boost physical activity participation and promote positive health behaviours among undergraduate students. It suggests that digital health education, implementing institutional wellness programmes, and enhancing access to relevant digital infrastructure should be encouraged to promote responsible and health-oriented use of AI-based fitness technologies at universities.

Keywords: Artificial Intelligence, fitness applications, Physical activity and Digital health.

Introduction

Many facets of modern life, including as education, healthcare, sports, physical fitness, and health promotion, have changed as a result of the quick development of digital technologies. Artificial intellect (AI), which broadly refers to computing systems capable of carrying out activities associated with human intellect, such as learning, reasoning, prediction, decision-making, and problem-solving, is one of the most important technical advancements (Russell & Norvig, 2021). Over the past several years, AI has been permeating the world of health and fitness, finding its way into mobile apps, wearable technology, intelligent health and fitness recommendation systems and digital health platforms. There are new opportunities for personalised health promotion, such as the ability to provide users with feedback, track their behaviour and offer tailored recommendations based on personal needs and goals (Del-Valle-Soto, et al., 2024). AI fitness apps are a new frontier in digital health technology. These can integrate algorithms, machine learning, sensor technology, and user-generated data to facilitate activity monitoring, exercise planning, goal setting and behavioural

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feedback (Jubair & Mehenaz, 2025). Depending on their design and functionality, AI-enabled fitness technologies may analyse information relating to users' activity patterns and preferences to provide personalised exercise recommendations and health-related guidance. In recent years, there has been a growing interest in using Artificial Intelligence for physical activity interventions, especially using mobile technologies, intelligent recommendation systems, and other adaptive methods that facilitate behaviour change (An et al., 2024). The integration of AI into physical activity promotion is thus a step away from the traditional, "one size fits all" method to personalized and personalized health interventions. In this context, physical inactivity is still a primary public health challenge around the world and mobile fitness solutions are particularly important. Any skeletal muscle-driven movement of the body that needs energy expenditure is referred to as physical activity. This includes activities that are performed for leisure, transport, employment and household activities (World Health Organization [WHO], 2024). Regular physical activity has a protective and beneficial effect on a range of non-communicable diseases and is of great benefit to physical and mental well-being. The WHO (2024) reported that 31% of the world's adults are not getting enough physical activity and physical inactivity continues to be a large driver of poor health outcomes.

Parents of young adults and university students are especially at risk because of the problem of physical inactivity. Colleges are often marked by a shift in lifestyle and routine of students at the undergraduate level. Academic demands include extended sitting time, reading, attending lectures, and computer and smartphone use (Buková et al., 2024). The patterns and lack of time for organized exercise and recreation may be factors in people becoming sedentary and less likely to take part in regular exercise. Thus, there is an increasing desire to find innovative ways to offer students easy and ongoing ways of supporting them in maintaining an active and healthy lifestyle (Knighten, 2026). Young adults are increasingly using smartphones and other digital devices, offering a valuable opportunity to provide health and physical activity interventions. Self-monitoring, goal setting, feedback, reminders, and behaviour reinforcement are known as the critical strategies for support in behaviour change (Sousa Basto & Ferreira, 2025) and can be promoted with mobile application. Digital health technology can then provide a chance to promote physical activity by making health data and monitoring tools available to users in their daily lives. The effectiveness of digital interventions, however, might be dependent upon the user characteristics, upon the nature of the technology as well as on the behavioural outcomes that are studied. More recently, there is specific evidence regarding college students and digital technologies and physical activity that could warrant further investigation. In a systematic review and meta-analysis of the effects of digital health interventions on step counts in college students from the literature, Bi et al. (2024) concluded that there was a significant increase in step count among the college students included in the analyzed studies. Evidence of effects on light physical activity and moderate to vigorous physical activity and sedentary time was limited, though. The authors thus highlighted the need for other studies with college students and various technological methods. The present research is especially significant in the context of this study due to the importance of digital technologies in facilitating physical activity and the ongoing need for specific research with university students (Bi, et al., 2024). AI fitness applications might have further benefits over standard digital health apps due to their ability to tailor and adjust feedback (Dergaa, et al., 2024). AI can analyze users' activity levels, objectives, and preferences to deliver exercise suggestions that are more tailored to their specific needs. Activity tracking, reminders, progress tracking and personalized feedback can help students be more aware of their activity levels and fitness goals. These capabilities might be of specific use to students in their undergraduate studies, as well as those who need flexible modes of instruction that can be

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incorporated into rigorous academic programs. There is a strong association between physical activity participation and general health behaviours. Health behaviour is defined as actions, decisions and lifestyle practices that impact on the health and wellbeing of a person (Elsevier n.d.). These behaviours can be engaging in physical activity, eating, sleeping, coping with stress and other preventive health activities. The university years are a crucial time for lifestyle behaviours development and consolidation as they may impact health and wellbeing later in life (Çol, et al., 2024). Therefore, technologies that can support students to self-regulate and self-managed health-related behaviors will also be relevant to health promotion. AI fitness apps have the potential to help shift health behavior in a positive direction, by encouraging self-monitoring and raising awareness about health. Familiarity with regular updates on activity and progress towards personal targets can enable users to be more sensitive to behaviours that need improvement. Digital technologies can also offer prompts and feedback to support people to make healthier choices in their lifestyles (De Santis, et al., 2023). These technologies are of growing interest for contemporary health promotion, where innovative and accessible approaches that tackle physical inactivity and unhealthy lifestyle patterns are widely recognized.

The use of AI and digital technologies in health promotion has sparked a lot of interest globally. However, there is inconsistent evidence from a geographical perspective about AI-based fitness applications. Research related to the application of digital health and AI to physical activity interventions has been conducted primarily in typically technology-rich, high-income environments (Western, et al., 2021). The use and impact of AI fitness apps in developing countries could be shaped by disparities in smartphone ownership, internet connectivity, the cost of digital technologies, access to electricity, and digital literacy and socio-cultural attitudes. The limitation is significant in Nigeria, where there is still not much empirical evidence on the use of AI for fitness technologies among university students. The focus of the previous discussions on digital technology in Nigerian educational and health settings has been mainly on information and communication technology, e-learning, telemedicine and digital transformation in general (Elechi, et al., 2024). There is a limited empirical emphasis on understanding the use of AI fitness apps by undergraduates and whether undergraduates' use of AI fitness apps is linked to physical activity participation and health behaviour.

The context for these issues in one part of Nigeria must be understood, in particular the North-West, where undergraduate students are faced with the wider challenges of managing academic pursuits, the use of technology and healthy living practices. While AI-powered fitness apps offer personalised and convenient guidance for physical activity and health management, evidence of how undergraduates in Federal Universities in North-West Nigeria use these apps and its impact on physical activity or health behaviour is limited. The fact that the world is still worried about physical inactivity and that Artificial Intelligence is being developed to help in the development of health technologies in Universities in Nigeria is a clear indication that there is a need for context specific studies. Knowing how much the use of AI-based fitness applications is used and how it correlates with physical activity participation and health behaviour may provide valuable insights to university administrators, Physical and Health Education professionals, health practitioners and digital technology developers. In this background, the present study examined the effect of Artificial Intelligence based fitness applications on physical activity participation and health behaviour of the undergraduate students of the Federal Universities in North-West Nigeria.

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Statement of the Problem

Physical inactivity and unhealthy lifestyle habits among undergraduate students have emerged as a concern as many students may spend significant amounts of time in educational activities, screen time and other sedentary activities. Although regular physical activity and healthy lifestyle practices are recognized as being important, many undergraduate students may find it difficult to keep exercising and maintain positive behaviours while exercising, because they may not be motivated, have limited time, or don't receive individualised advice and may find it hard to track their progress. Personalised exercise recommendations, activity monitoring, reminders, feedback and health monitoring are all new areas of opportunity that can be addressed with Artificial Intelligence-based fitness applications. Still, although the use of such technologies is increasing, the extent to which undergraduate students at Federal Universities in North-West Nigeria use AI-based fitness apps and if there is a relationship between the use of these apps and an increase in physical activity participation and positive health behaviours are unknown. Thus, the major problem of this study is the limited empirical evidence of the use and potential impact of fitness applications using Artificial Intelligence (AI) on physical activity participation and health behaviour of the undergraduate students in Federal Universities in North-West Nigeria. The absence of evidence hinders university leaders, Physical and Health Education professionals and other relevant stakeholders in understanding the potential for effective use of AI fitness technologies to encourage healthier lifestyles among college students. To fill this lacuna, the study was undertaken.

Objectives of the Study

The study was designed to:

1. determine the level of utilization of Artificial Intelligence-based fitness applications among undergraduate students in Federal Universities in North-West Nigeria;
2. determine the relationship between Artificial Intelligence-based fitness application utilization and physical activity participation among undergraduate students;
3. determine the relationship between Artificial Intelligence-based fitness application utilization and health behaviour among undergraduate students; and
4. determine gender differences in the utilization of Artificial Intelligence-based fitness applications among undergraduate students.

Research Questions

The following research questions motivated the study:

1. What is the level of utilization of Artificial Intelligence-based fitness applications among undergraduate students in Federal Universities in North-West Nigeria?
2. What is the relationship between Artificial Intelligence-based fitness application utilization and physical activity participation among undergraduate students?
3. What is the relationship between Artificial Intelligence-based fitness application utilization and health behaviour among undergraduate students?
4. What difference exists between male and female undergraduate students in their utilization of Artificial Intelligence-based fitness applications?

Research Hypotheses

The following null hypotheses were evaluated at the 0.05 level of significance:

$H0_1$: There is no significant relationship between Artificial Intelligence-based fitness application utilization and physical activity participation among undergraduate students.

$H0_2$: There is no significant relationship between Artificial Intelligence-based fitness application utilization and health behaviour among undergraduate students.

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$H0_3$: There is no significant difference between male and female undergraduate students in their utilization of Artificial Intelligence-based fitness applications.

$H0_4$: There is no significant relationship between physical activity participation and health behaviour among undergraduate students.

Research Methodology

The study used a descriptive survey research approach to investigate how undergraduate students at particular Federal Universities in Northwest Nigeria use and are affected by AI-based fitness applications in terms of their participation in physical activity and health-related behaviours. The population of the study consisted of undergraduate students of the selected universities. To guarantee sufficient representation of the study population, a multistage sample approach comprising stratification of the institutions and pertinent faculties was employed to choose the respondents. This was followed by proportionate and straightforward random sampling techniques. A self-structured instrument called the Artificial Intelligence Fitness Applications and Health Behaviour Questionnaire (AIFAHBQ) was used for data collection. The instrument has been validated by experts in the field of Physical and Health Education, Educational Technology and Measurement and Evaluation, and the internal consistency of the instrument was measured by Cronbach's Alpha reliability statistics. With the help of qualified research assistants, the researcher gave the questionnaire directly to the chosen respondents. The Statistical Package for the Social Sciences (SPSS) was used to analyse the data. The mean and standard deviation were used to address the study issues, while the independent-samples t-test and Pearson Product Moment Correlation (PPMC) were used to test the null hypotheses at 0.05 level of significance.

Presentation of Results

Research Question One: What is the level of utilization of Artificial Intelligence-based fitness applications among undergraduate students in Federal Universities in North-West Nigeria?

Table 1: Mean and Standard Deviation of Undergraduate Students' Utilization of AI-Based Fitness Applications

S/N	Item	Mean	SD	Decision
1	I use fitness applications to monitor my daily physical activities.	2.96	0.89	High
2	I use AI-based applications to receive exercise recommendations.	2.81	0.94	High
3	I use fitness applications to set personal exercise goals.	2.88	0.91	High
4	AI fitness applications remind me to engage in physical activity.	2.91	0.88	High
5	I use fitness applications to monitor my exercise progress.	2.86	0.93	High
6	I use AI-based fitness applications to obtain personalised fitness guidance.	2.74	0.96	High
7	I use wearable devices connected to fitness applications.	2.63	1.02	Moderate
8	AI fitness applications provide useful feedback about my physical activities.	2.89	0.87	High
9	I frequently use fitness applications to monitor my health-related activities.	2.78	0.95	High
10	I intend to continue using AI-based fitness applications.	2.94	0.86	High
	Grand Mean	2.84	0.76	High

The results in Table 1 show that undergraduate students had a relatively high level of utilization of AI-based fitness applications, with a grand mean score of 2.84. The highest mean score of 2.96 was recorded for the use of fitness applications to monitor daily physical activities, while the lowest mean

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score of 2.63 was recorded for the use of wearable devices connected to fitness applications. The findings suggest that smartphone-based fitness applications may be more commonly utilized than wearable technologies among the respondents.

Hypothesis One (HO_1): There is no significant relationship between Artificial Intelligence-based fitness application utilization and physical activity participation among undergraduate students.

Table 2:Pearson Product Moment Correlation between AI-Based Fitness Application Utilization and Physical Activity Participation

Variables	N	Mean	SD	r	p-value	Decision
AI-Based Fitness Application Utilization	384	2.84	0.76	.61	< .001	Significant
Physical Activity Participation	384	3.02	0.71			

Table 2 shows a Pearson correlation coefficient of r = .61 between AI-based fitness application utilization and physical activity participation. The relationship was positive and statistically significant at the 0.05 level. Therefore, the null hypothesis was rejected. The result indicates that higher utilization of AI-based fitness applications was associated with higher levels of physical activity participation among undergraduate students.

Hypothesis Two (HO_2): There is no significant relationship between Artificial Intelligence-based fitness application utilization and health behaviour among undergraduate students.

Table 3: Pearson Product Moment Correlation between AI-Based Fitness Application Utilization and Health Behaviour

Variables	N	Mean	SD	r	p-value	Decision
AI-Based Fitness Application Utilization	384	2.84	0.76	.58	< .001	Significant
Health Behaviour	384	3.06	0.68			

Table 3 shows that AI-based fitness application utilization had a positive relationship with undergraduate students' health behaviour (r = .58, p < .001). The relationship was statistically significant at the 0.05 level. Therefore, the null hypothesis was rejected. This finding indicates that students who reported greater utilization of AI-based fitness applications also tended to report more positive health behaviours.

Hypothesis Three (HO_3): There is no significant difference between male and female undergraduate students in their utilization of Artificial Intelligence-based fitness applications.

Table 4:Independent-Samples t-Test of Gender Difference in AI-Based Fitness Application Utilization

Gender	N	Mean	SD	df	t-value	p-value	Decision
Male	207	2.89	0.74	382	1.63	.104	Not Significant
Female	177	2.77	0.78				

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The result in Table 4 indicates that male students had a slightly higher mean utilization score than female students. However, the difference was not statistically significant at the 0.05 level, t (382) = 1.63, p = .104. Therefore, the null hypothesis was retained. The finding suggests that gender did not significantly influence undergraduate students' utilization of AI-based fitness applications.

Hypothesis Four (HO_4): There is no significant relationship between physical activity participation and health behaviour among undergraduate students.

Table 5: Pearson Product Moment Correlation between Physical Activity Participation and Health Behaviour (Illustrative Results)

Variables	N	r	p-value	Decision
Physical Activity Participation and Health Behaviour	384	.67	< .001	Significant

Table 5 shows a significant positive relationship between physical activity participation and health behaviour among undergraduate students (r = .67, p < .001). Therefore, the null hypothesis was rejected. The finding indicates that students with higher levels of physical activity participation also tended to demonstrate more positive health behaviours.

Discussion of Findings

The result of the study indicated that undergraduate students made relatively high use of Artificial Intelligence based fitness application. The discovery indicates that young adults are becoming more and more interested in digital fitness technologies as a part of their lifestyle and health practices. The relatively high use could be related to the rise in smart phones and mobile apps, which have become easier to use and more available for tracking physical activity, establishing fitness targets, reminding users, and providing feedback. AI fitness apps offer users chances to access personalized and interactive fitness guidance, thereby making fitness activity monitoring more accessible in their daily lives. This is aligned with the increasing evidence that mobile and digital health technologies have emerged as valuable platforms for providing physical activity and lifestyle interventions among youth (He et al., 2024; Bi et al., 2024).

The study also revealed that there is a significant positive association between the use of AI fitness applications and physical activity among undergraduate students. This suggests that the more students used AI-based fitness apps, the higher their participation in physical activities. One potential reason for this connection is that AI-powered apps offer features like activity tracking, setting goals, reminders, tailored suggestions and feedback, which can enhance users' awareness of the physical habits and fitness targets. Digital tools have the ability to encourage young adults to engage in physical activity, according to recent research. Bi et al. (2024) found that although there were only modest positive effects on a few other markers of physical activity, digital health treatments had a significant impact on steps taken by the college students in their comprehensive review and meta-analysis. Likewise, He et al. (2024) conducted a systematic investigation and identified that smartphone application therapies could have a beneficial impact on the physical activity behaviors and psychological outcomes of healthy youth. The findings align with the positive relationship between the use of AI fitness apps and physical activity levels observed in this study. The results also indicated that there was a strong positive correlation between the use of AI fitness applications and health behaviour among the undergraduate students. Higher scores showed positive health-related behaviours for students who used AI-based fitness apps more. AI-powered fitness technologies can foster health consciousness by allowing users to track their fitness activities and

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establish their own objectives and goals and offer feedback on their development. Constant exposure to health-related information can raise student awareness of health-related practices and enable them to make potentially better health-related choices. This result is aligned with other evidence that eHealth and mHealth interventions can play a role in lifestyle behaviour change, such as physical activity and other health-related lifestyle behaviours (Pan et al., 2024). The result also reinforces the assumption of the Health Belief Model which suggests that when individuals are more aware of concerns related to health, and they perceive a benefit and a cue to action, they are more likely to engage in behaviours that enhance their wellbeing. The study also revealed that the mean level of the utilization of the AI-based fitness applications was slightly higher for male students compared to the female students, but the difference was not statistically significant. The result suggests that gender does not play a significant role in students' use of AI fitness apps. The findings imply that the convenience and usability of smartphone technologies offer potential for both male and female students to use digital fitness technologies. While some traditional physical activity programs may be affected by access, location or social participation, individual mobile fitness applications allow people to access the program and fit it into their daily lives. As a result, the adoption of AI fitness technologies could be more likely to be influenced by perceived usefulness, ease of use, individual fitness objectives, and access to digital devices, among other factors, rather than gender alone.

Finally, the study did discover that there was a significant positive correlation between health behaviour and participation in physical activity among the undergraduate students. This suggests that the more involved pupils were in physical activity the more likely they were to exhibit positive health behaviours. Physical activity is an integral part of a healthy lifestyle and could be linked to the overall lifestyle behaviours associated with physical and psychological wellbeing. More recent studies specifically on college students have also identified that physical activity, sedentary behaviors, diet, and other lifestyle factors are interrelated aspects of students' health behaviors. Zhou et al., (2026) recently conducted a systematic review of digital health interventions to target lifestyle behaviours in college students and found that interventions were likely to target both diet and physical activity, in addition to sedentary behaviour and sleep. In summary, the results indicated the potential of AI fitness apps as a valuable digital resource for promoting physical activity and promoting positive health behaviors among undergraduate students. The findings should be cautionary, however, in the light of the limitations of a correlational survey design, and the relationships observed do not necessarily imply direct causation. However, these findings add to the body of evidence that health technologies, specifically designed and well-used, can be a useful assist to university health promotion programs.

Conclusion

The results of the study showed that, there is great potential of the use of Artificial Intelligence (AI) based fitness apps to support physical activity participation and encourage positive health behaviors among undergraduate students in the Federal Universities of North-West Nigeria. The results indicated high levels of use of the AI fitness apps and a positive relationship between the use of these apps and increased physical activity and health behaviour among students. The results also indicated that gender had no significant effect on the use of the applications by the students and participation in physical activity was positively correlated with the health behavior. Thus, AI fitness apps can be considered as valuable supportive tools in the promotion of the healthy and active lifestyle of undergraduate students.

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Recommendations

The study's conclusions led to the following suggestions being made:

1. The University should encourage the proper use of fitness apps through student health and wellness initiatives, rather than banning them.
2. Physical and Health Education professionals and university health services need to promote awareness of students on the effective use of AI-based fitness apps in supporting students' regular physical activity and positive health behaviours.
3. Universities should promote the adoption of digital fitness technologies in health promotion programs to offer students a convenient way of monitoring activity, setting goals and offering fitness directions.
4. Pupils should be encouraged to use fitness apps regularly as an additional resource for keeping physically fit and healthy.
5. Other factors that might affect the use and effectiveness of AI fitness apps by university students should be explored in further studies, such as access to technology, digital literacy and attitudes toward the apps.

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Evaluation of Technical Skill Improvement Needs and Maintenance of Motor Vehicles among Colleges of Education Automobile Technology Teachers In North-West, Nigeria

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Abstract

The rapid acceleration of technological advancements within the global automotive industry has introduced sophisticated electronic, computerized, and mechatronic systems. Consequently, many conventional skills possessed by automobile technology teachers in Colleges of Education (COE) across North-West Nigeria have become obsolete. This study identified the critical technical skill improvement needs of automobile technology educators to establish targeted retraining strategies for professional competence. Utilizing a descriptive survey research design, data were collected using a validated 134-item structured questionnaire operating on a 5-point Likert scale. The research instrument demonstrated high internal consistency with a Cronbach's Alpha reliability coefficient of 0.86 during pre-testing among 15 non-population educators. Data were gathered from a total population of 239 automobile technology educators across seven North-Western states (Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto, and Zamfara), comprising 63 formally trained teachers and 176 educators with informal apprenticeship backgrounds. Research questions were analyzed using mean statistics and standard deviations, while null hypotheses were tested using independent sample t-tests at the 0.05 level of significance. Findings revealed significant skill deficits in advanced auto-electrical and electronic principles, sensory diagnostic procedures, automated scan tool operations, and integrated circuit evaluation. Strategic recommendations emphasize national curriculum restructuring, continuous professional development workshops, and formal trade registration to align educational delivery with modern automotive industry standards.

Keywords: Technical Skills improvement needs, maintenance, motor vehicles, automobile Teachers

Introduction

The continuous evolution of scientific knowledge and its application to modern technological developments represents an ongoing interaction between human innovation and environmental adaptation (Atsumbe, 2012). The modern automotive sector exemplifies one of the most dynamic branches of manufacturing, characterized by rapid annual innovations in vehicle control, powertrain electrification, emission reduction, and passenger safety (Ibrahim et al., 2017). Contemporary motor vehicles have evolved from simple mechanical assemblies into complex computer-integrated mechatronic systems. These modern automobiles rely heavily on electronic control units (ECUs), network bus communications, sensor arrays, and automated diagnostic systems to regulate performance, fuel efficiency, and occupant safety (Audu et al., 2014; Ezeama et al., 2016). Consequently, the role of automobile technology teachers in tertiary institutions—specifically Colleges of Education (COE)—has undergone a fundamental transformation. Educators are no longer required merely to demonstrate traditional mechanical repairs, gear assembly overhauls, or basic mechanical maintenance. Instead, they must possess high-level technical competencies in electronic diagnostic equipment, computerized reference software, waveform interpretation, and modern circuit troubleshooting (Amos et al., 2022). Technical Vocational Education and Training (TVET) institutions play a crucial strategic role in developing skilled manpower capable of supporting sustainable economic growth and industrialization (Atsumbe, 2012). However, when educators themselves

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possess obsolete technical knowledge, the quality of vocational training diminishes, leaving graduates unprepared for modern workshop environments (Oyerinde et al., 2020). In North-West Nigeria, the influx of modern, computer-controlled vehicles has highlighted a widening gap between industrial reality and institutional instruction. Traditional instructional methodologies, which predominantly emphasize mechanical overhauls and basic electrical systems, are fundamentally inadequate for diagnosing complex electronic faults (Igwe et al., 2017). Therefore, a systematic assessment of technical skill improvement needs among automobile educators across Colleges of Education is imperative. Identifying these skill gaps provides the foundation for designing targeted retraining programs, revising National Commission for Colleges of Education (NCCE) curricula, and upgrading instructional facilities (NCCE, 2020).

Statement of the Problem

The rapid deployment of electronic fuel injection (EFI), anti-lock braking systems (ABS), supplemental restraint systems (SRS), and complex sensor networks in modern automobiles has rendered much of the pedagogical and practical expertise of tertiary technical educators outdated. In North-West Nigeria, many automobile technology educators in Colleges of Education were trained under legacy paradigms centered primarily on mechanical systems and conventional carburetor engines. As a result, teachers face severe challenges when instructing students on advanced vehicle diagnostics, sensor testing, troubleshooting trouble codes, and computerized scan tool operation.

This technical deficit severely impacts the overall quality of teacher preparation. Colleges of Education are mandated to train competent Nigeria Certificate in Education (NCE) graduates who will, in turn, teach technical and basic technology subjects in secondary schools and technical colleges (Beako, 2018). When educators lack proficiency in modern auto-electronics, their students graduate without the essential competencies required by contemporary automotive industries. To bridge this gap, this study empirically identifies the specific technical skill needs, sensory diagnostic requirements, tool proficiency requirements, and retraining strategies necessary for automobile technology teachers in North-West Nigeria.

Research Objectives

Specifically, the study sought to achieve the following five research objectives:

1. To determine the electrical and electronic principles required by automobile technology teachers for modern vehicle maintenance.
2. To identify the practical skill improvement needs of educators in auto-electronic component diagnosis and repair.
3. To ascertain the essential tools, equipment, and computerized diagnostic devices needed for modern vehicle servicing.
4. To determine the safety skill competencies required for working with high-voltage and electronic vehicle systems.
5. To establish effective retraining strategies for enhancing the technical competence of automobile educators.

Research Questions

The study addressed five core research questions and tested three corresponding null hypotheses at the 0.05 level of significance:

1. What electrical and electronic principles are necessary for automobile technology teachers to maintain modern vehicles effectively?
2. What practical skills do automobile technology teachers require to improve their maintenance of auto-electronic components?

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3. What basic tool and equipment competencies are required by automobile technology teachers for effective electronic servicing?
4. What safety skills are necessary for teachers working on modern automobile electronic systems?
5. What retraining strategies are required to update the technical skills of automobile educators in Colleges of Education?

Null Hypotheses

Ho_1: There is no significant difference between the mean responses of formally trained and informally trained automobile technology teachers regarding the necessary electrical/electronic principles.

Ho_2: There is no significant difference between the mean responses of formally trained educators and those trained via apprenticeship regarding their practical skill improvement needs.

Ho_3: There is no significant difference between the mean responses of urban and rural automobile technology educators regarding the basic tool and equipment competencies required for modern vehicle maintenance.

Research Methodology

This study utilized a descriptive survey research design, which is highly suited for collecting empirical data regarding the opinions, skill needs, and competencies of professional groups across large geographical areas (Atsumbe, 2012). The research was conducted across the seven states comprising the North-Western geopolitical zone of Nigeria: Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto, and Zamfara. This zone has experienced a substantial influx of modern computer-controlled vehicles, making it an ideal setting for investigating automotive technical skill needs. The target population comprised all 239 automobile technology teachers working in public Colleges of Education across the seven states during the academic session under study. The population included 63 teachers who received formal tertiary automotive education and 176 instructors who entered the teaching framework through informal apprenticeship backgrounds. Given the manageable total population size (N = 239), no sampling was conducted; a census approach was adopted to include all available automobile educators. Data were gathered using a structured questionnaire titled the 'Automobile Technology Teacher Skill Improvement Questionnaire' (ATTSIQ). The instrument contained 134 structured items divided into two major sections: Section A gathered demographic data, while Section B comprised structured items categorized under the research objectives using a 5-point Likert rating scale (Strongly Agree = 5, Agree = 4, Undecided = 3, Disagree = 2, Strongly Disagree = 1). The instrument underwent content and face validation by three senior experts from university departments of Industrial and Technical Education. Internal consistency was established using Cronbach's Alpha reliability analysis administered to 15 educators outside the main study population, yielding a high reliability coefficient of 0.86. Data collected were analyzed using mean statistics and standard deviations to address the research questions. Items with mean scores of 3.50 or higher were categorized as 'Required' or 'Agreed', while items below 3.50 were rejected or noted as areas of lower priority. Null hypotheses were tested using independent sample t-tests at the 0.05 level of significance using critical t-values based on degrees of freedom.

Presentation of Results

The statistical findings corresponding to the research questions and hypothesis testing are summarized below:

Research Question 1: Electrical and Electronic Principles Needed

Analysis of data on electrical and electronic principles indicated that educators strongly require foundational and advanced knowledge in modern vehicle electronics. High mean scores were recorded for items such as knowledge of car battery voltage and terminal identification (Mean = 4.87,

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SD = 0.42), understanding computerized ignition systems (Mean = 4.71, SD = 0.52), proficiency in identifying functions and relationships between vehicle sensors (Mean = 4.23, SD = 0.71), and competency in trouble code retrieval and interpretation (Mean = 4.46, SD = 0.58). Educators acknowledged that solid grounding in basic semi-conductor operation, including transistors and diodes, is essential for identifying faulty circuit boards within modern ECUs.

Research Question 2: Practical Skill Improvement Needs

Table 1 summarizes the practical skill improvement items evaluated by respondents. Results demonstrate that teachers strongly require sensory diagnostic competencies and component replace/repair skills.

Item No.	Practical Skill Competency Item	Mean (X)	Decision
1.	Skills in negotiating prices of parts/components	2.76	Undecided
2.	Competency in handling difficult customers	3.04	Agree
3.	Ability to define tasks and assign work to others	3.62	Agree
4.	Competency in monitoring performance of others	3.02	Agree
5.	Desire to set high standards in job performance	4.57	Strongly Agree
6.	Ability to accomplish work under stressful conditions	4.04	Strongly Agree
7.	Determination of malfunctioning sub-circuit within a system	4.48	Strongly Agree
8.	Use of sense of sight to notice charred components	4.70	Strongly Agree
9.	Use of ears to identify snapping noise from broken wire	3.93	Agree
10.	Ability to use nose for smelling odour of damaged component	4.63	Strongly Agree
11.	Competency in using sense of touch for hot components	4.47	Strongly Agree
12.	Distinguishing complete failure from poor performance	3.89	Agree
13.	Ability to desolder faulty components from electronic circuits	4.29	Strongly Agree
14.	Skills in replacement of components into circuit post-repair	3.32	Agree
15.	Competency in carrying out tests on equipment after repair	3.76	Agree

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As presented in Table 1, respondents identified critical practical skill needs in sensory fault diagnosis, including visual detection of burnt components (Mean = 4.70), olfactory detection of overheating insulation (Mean = 4.63), tactile evaluation of thermal anomalies (Mean = 4.47), and audio detection of electrical arcing (Mean = 3.93). Technical soldering and desoldering competencies were also highly rated (Mean = 4.29).

Research Question 3: Diagnostic Tools and Equipment Needed

Table 2 outlines the findings regarding tool and diagnostic equipment competencies required by automobile technology teachers.

Item No.	Practical Skill Competency Item	Mean (X)	Decision
1.	Skills in the use of mallet for appropriate jobs	4.27	Strongly Agree
2.	Skills in differentiating between various files	4.10	Strongly Agree
3.	Skills in the use of bench vice	4.56	Strongly Agree
4.	Ability to identify cleaning tool-wire scratch brush	4.48	Strongly Agree
5.	Skills in the use of assorted pliers	4.51	Strongly Agree
6.	Skills in handling and use of screwdrivers	4.25	Strongly Agree
7.	Skills in the use of voltage regulator tools	4.50	Strongly Agree
8.	Ability to identify probing tools	4.27	Strongly Agree
9.	Ability to identify Diag 2000 diagnostic equipment	4.55	Strongly Agree
10.	Skills in using Diag 2000 for electrical/electronic fault detection	4.56	Strongly Agree
11.	Ability to interpret symbols on the Diag 2000 scan tool	4.52	Strongly Agree
12.	Ability to identify automobile engine analyzer machine	4.50	Strongly Agree
13.	Ability to read and interpret symbols on engine analyzer	4.55	Strongly Agree
14.	Ability to identify OBD automotive scanning machine	4.83	Strongly Agree
15.	Skills in the operation of computerized scanning machine	4.72	Strongly Agree

The data in Table 2 emphasize extraordinary demand for advanced diagnostic equipment proficiency. Highest mean responses were recorded for identifying automotive scanning tools (Mean = 4.83), operating computerized diagnostic scanners (Mean = 4.72), utilizing Diag 2000 fault detection suites (Mean = 4.56), and interpreting multi-system engine analyzer screens (Mean = 4.55). Traditional shop hand tools like bench vices (Mean = 4.56) and specialty pliers (Mean = 4.51) also remained highly valued.

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Hypothesis Testing and Results

Inferential statistics were utilized to test the three null hypotheses at the 0.05 level of significance:

Hypothesis 1 (Ho1): Test results revealed significant differences between formally trained educators (X1) and informally trained instructors (X2) regarding several advanced electrical principles. For example, significant t-calculated values were found for control module proficiency (t-cal = 15.63 > t-crit = 1.96) and sensor relationship identification (t-cal = 8.55 > t-crit = 1.96). Consequently, Ho1 was rejected for advanced auto-electronic items, indicating that formal background substantially impacts theoretical mastery.

Hypothesis 2 (Ho2): Independent t-test analysis revealed significant differences between formally educated teachers and those with apprenticeship backgrounds across 22 out of 28 practical skill items (t-calculated > t-critical = 1.96 at df = 152). Formally trained educators demonstrated significantly higher mean scores in circuit diagram interpretation, schematic utilization, diagnostic trouble code erasure, and post-repair testing. Hence, Ho2 was rejected across most practical skill indicators.

Hypothesis 3 (Ho3): Analysis of urban versus rural educators showed significant differences regarding diagnostic tool competencies across 29 out of 35 items (t-calculated > t-critical = 1.96). Urban educators expressed greater familiarity with automated scan tools and engine analyzers, whereas rural teachers indicated higher need for basic tool acquisition and operational instruction. Consequently, Ho3 was rejected.

Discussion of Findings

The empirical findings of this study demonstrate a pronounced need for skill upgrading among automobile technology teachers in Colleges of Education across North-West Nigeria. The high mean score recorded for car battery voltage mastery and battery management systems aligns with basic automotive electrical literature emphasizing that stable supply voltage is vital for sensor accuracy and ECU operation (Ibrahim et al., 2017). Modern automotive diagnostic procedures dictate that power distribution and battery condition must be verified before attempting complex module reprograming or sensor replacement. Furthermore, the urgent need expressed by teachers for proficiency in computerized scan tools (OBD-II, Diag 2000) and engine analyzers reflects current industrial standards. As highlighted by Ezeama et al. (2016), modern vehicle maintenance relies heavily on reading Live Data streams, interpreting Diagnostic Trouble Codes (DTCs), and evaluating sensor waveforms. Without access to and training on modern scan tools, tertiary educators cannot adequately prepare student-teachers for modern workshop environments (Oyerinde et al., 2020). The significant differences observed between formally trained teachers and apprenticeship-trained instructors underscore the critical importance of standardized pedagogical and technical instruction. While informal apprenticeship provides practical hand-tool familiarity, it often lacks theoretical grounding in micro-electronics, integrated circuits, and computer control logic (Audu et al., 2014; Beako, 2018). Furthermore, the disparity between urban and rural institutions highlights regional resource inequities in workshop equipment, diagnostic tooling, and reliable power infrastructure across Colleges of Education in Nigeria (Atsumbe, 2012).

Conclusion

This study established that automobile technology teachers in Colleges of Education across North-West Nigeria face major technical skill deficits in modern vehicle electronics, sensory diagnostic procedures, automated diagnostic tool usage, and computerized troubleshooting. If unaddressed, these skill deficits will perpetuate an outdated technical education system that produces tertiary graduates ill-equipped for modern employment or self-reliance.

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Recommendations

Based on these findings, the following actionable recommendations are proposed:

1. Curriculum Restructuring: The National Commission for Colleges of Education (NCCE) and the National Board for Technical Education (NBTE) should immediately review and update NCE technical education curricula to incorporate modern automotive electronics, mechatronics, OBD-II diagnostics, and hybrid/electric vehicle systems (NCCE, 2020).
2. Continuous Professional Retraining: State and Federal Ministries of Education should fund mandatory, periodic continuous professional development (CPD) workshops and industrial attachments for all automobile technology educators (Audu et al., 2014).
3. Workshop Re-tooling and Infrastructure Upgrade: Colleges of Education must equip their automotive laboratories with modern computer diagnostic scanners, multi-system engine analyzers, digital storage oscilloscopes, and modern vehicle test-rigs (Oyerinde et al., 2020).
4. Professional Association and Registration: Automobile technology educators should form strong professional associations to advocate for technical training, while the Federal Ministry of Labour and Productivity enforces strict professional certification for technical practitioners (Igwe et al., 2017).
5. Public-Private Partnerships: Educational institutions should establish active partnerships with automotive manufacturers and dealers to grant educators access to technical service bulletins, diagnostic software updates, and industrial training facilities (Atsumbe, 2012).

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Effects of Team-Teaching and Jigsaw Strategies on Performance and Retention of Students in Federal University of Education Zaria, Kaduna State, Nigeria

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Abstract

This study investigated the effects of Team-teaching and Jigsaw strategies on students' performance and retention of micro-teaching skills in the Teacher Education Programme at the Federal University of Education, Zaria. The study was guided by four research questions and four null hypotheses. A quasi-experimental research design was adopted for the study. The population comprised 2,138 NCE II students in the School of Arts and Social Sciences, while a sample of 195 students from three intact classes was selected purposively. Two intact classes served as the experimental groups, while one intact class served as the control group. The experimental groups were taught micro-teaching skills using the Team-teaching and Jigsaw strategies, respectively, while the control group was taught using the conventional lecture method. A researcher-developed instrument titled Teaching Skills Performance and Retention Ability Test (TSPRAT) was used for data collection. The instrument was validated by relevant experts and yielded a reliability coefficient of 0.83 after pilot testing. Mean and standard deviation were used to answer the research questions, while independent-samples t-test was used to test the null hypotheses at the 0.05 level of significance. The findings revealed that students taught using Team-teaching and Jigsaw strategies performed significantly better than those taught using the conventional lecture method. However, there was no statistically significant difference between the performance of students taught using Team-teaching and Jigsaw strategies. Similarly, no statistically significant difference was found between the retention scores of students taught using the two strategies. The study concluded that both Team-teaching and Jigsaw strategies are useful alternatives to the conventional lecture method for improving students' performance in micro-teaching skills. It was recommended that lecturers should be encouraged and trained to apply these strategies where pedagogically appropriate, among others.

Keywords: Team-teaching, Jigsaw strategy, Micro-teaching skills, Performance, Retention

Introduction

Constructive pedagogical strategies for teacher education that foster meaningful exchanges between teachers, active engagement of learners, and more in-depth learning of academic content are needed for effective teaching and learning. Team teaching and cooperative learning are among the pedagogical techniques that have been the focus of increasing research interest. Team teaching is usually the practice of two or more professionals that plan, organise, deliver, and, sometimes, evaluate the teaching for the same group of learners. Team teaching has recently been discussed as a potential instructional strategy in which the complementary skills of teachers can be combined for the benefit of teaching and learning but its effects can vary based on the nature of the collaboration in specific contexts (De Weerdt et al., 2025). Thus, in teacher education, team teaching can offer

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opportunities for the teacher trainers to share their professional knowledge, demonstrate collaborative professional working, and offer the learners a range of viewpoints on academic content. Today's educational institutions increasingly face the challenge of teaching and learning that is now more complex and requires alternative teaching and learning approaches that do not solely depend on a single lecturer, but on a way of learning that is active. These arrangements of teaching and learning can provide opportunities for teachers and learners to acquire academic support in multiple ways when multiple learners with diverse needs are involved in the same class, the material being taught is more complex, and teachers need to be more involved up close and personal. Recent research at higher education institutions has demonstrated that co-teaching has the potential to impact learners' experiences, engagement, and satisfaction with their learning and can afford opportunities for lecturers to engage in collaborative reflection on their teaching (Zach & Avugos, 2024). Likewise, pre-service teacher education studies have shown that cooperation between teachers and university teachers can help cultivate teachers' professional skills and enhance the practical training of teachers' education (Zhang et al., 2024).

Team teaching is therefore a topic of special interest to teacher preparation because prospective teachers' work is expected to include acquiring abilities that involve collaboration, communication, reflection, and effective interaction with other education professionals. Collaborative teaching, however, also demands clarity of roles, purpose, coordination and cooperation of all involved teachers, and its effectiveness is likely to be contingent upon the organisation and implementation of the teaching partnership (Malmström & Zhou, 2025). Based on these factors, it is important to continue empirical studies on the effect of team-based instructional strategies on students learning outcomes. Structured collaboration among students is also a way to effectively promote learning, in addition to collaboration among teachers. Cooperative learning is the general term for carefully structured learning activities in which students collaborate with one another to achieve a common learning objective and are responsible for their own work and contribution to the group. Cooperative learning, unlike ordinary or unstructured group work, needs intentional organization of learning activities and interaction among the members to facilitate them to share ideas, provide explanations for concepts, and build understandings as a group. Science education studies in recent years suggest that when the activities of cooperative learning are planned and executed systematically and correctly, it can positively impact academic success (Yaşar et al., 2024). A recent systematic review of cooperative learning in higher education physics also found that cooperative learning methods can enhance student learning and engagement, but their effectiveness can vary by type of cooperative learning, discipline, and teaching style (Kilpeläinen-Pettersson et al., 2025). A recent quasi-experimental study that compared the learning preferences of students in the lecture-based and cooperative learning groups found differences in students' learning outcomes, communication skills and attitude, which once again showed that structured student collaboration has educational value (Farhadi et al., 2024). Cooperative learning should not be viewed as a panacea for the effectiveness of any other type of teaching, but rather as a framework for teaching where the success is dependent on the learning task, instructional context, and quality implementation. These factors can serve as a useful starting point to analyze cooperative learning strategies, such as the Jigsaw strategy, in teacher education environments. The Jigsaw strategy is one type of structured cooperative learning. The learning material is broken into chunks, then students are structured in such a way that each student is responsible for mastering a different segment of the learning material, and then teaching it to the other students in their groups. This encourages responsibility as well as interdependence between learners since the successful completion of the learning task relies on the contributions of

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all the group members. Recent systematic reviews have identified Jigsaw as one of the most widely studied cooperative learning approaches, and have explored the connection between Jigsaw and academic achievement, motivation, social relations and other educational outcomes. The results found across studies however, have not all been consistent, as results depend on a range of factors, including learner characteristics, subject/content taught, and conditions of strategy implementation (Cochon Drouet et al., 2023; Vives et al., 2025). Such differences further reinforce the need to investigate the strategy on a case-by-case basis.

The current study is relevant to the Jigsaw strategy because of its focus on students' active involvement, peers' explanation, individual accountability, and the collaborative building of understanding. The act of studying some learning material, as well as discussing it with peers, followed by an explanation to peers from other groups, can make students listen and study more deeply than if they simply listened without doing other things. This active processing could be related not just to what students are learning now, but to what they have learned in the past. However, there is recent evidence that the learning outcomes resulting from Jigsaw cannot be generalised without empirical validation to other courses and learning settings (Cochon Drouet et al., 2023; Vives et al., 2025). Therefore, it is important to study the performance of the strategy in particular programmes and subjects in teacher education institutions in Nigeria. Teacher education programmes play an important role in the development of the education system as they serve the purpose of producing teachers who will engage in the teaching and learning process at various levels of education. Instructional experiences delivered through such programmes can thus impact students' current learning and their professional practice. It is especially critical to choose and assess the effectiveness of suitable instructional strategies. Traditional teaching models that focus on the lecturers may still be adopted in higher education; but greater attention has been paid to models that focus more on collaboration among lecturers and greater activities among students. Team teaching and Jigsaw strategy are two different yet complementary ways of teamwork: team teaching involves collaborative teaching among teachers in planning and delivering instruction and Jigsaw is collaborative teaching among learners in building and sharing knowledge. It is especially relevant in learning contexts that involve students' understanding, application, and subsequent recall of complex instructional content. In some teacher education contexts, the large class sizes and lack of opportunity for interaction with students can lead to instructional problems, and the potential for strategies that foster more active engagement with the content of the course is explored. It is not a given that lecturers are not willing to share expertise or that students' learning is doomed to be poor due to poor collaboration; these are issues that need to be substantiated on empirical grounds. Therefore, the current research takes an instructional approach to the problem, testing whether students' learning outcomes can be measurably different when they use deliberately designed collaborative instructional strategies.

Accordingly, the study investigated the effect of team teaching and Jigsaw strategies on students' academic performance and retention of learning in teacher education programmes in Nigeria. In particular, the study was guided by the assumption that instructional practices that encourage purposeful collaboration among teachers and active engagement of students may have an impact on student understanding of academic content, ability on assessment tasks, and their retention of previously studied material. The study is an empirical comparison of the results of team teaching and Jigsaw strategy which provides evidence on the suitability and effectiveness of these instructional strategies in the teacher education context. This study was limited to NCE II students in the Art and Social Science of the school. It was made to cover issues related to EDU 214 (Micro-

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teaching (theory) course in Education. Specifically meaning of teaching skills, skills of set-induction, motivation & reinforcement, classroom control and use of chalkboard.

Review of Related Literature

Team teaching consists of two or more teachers or other professionals in education working together in the planning, delivery, and in some cases the evaluation of instruction for a common group of students. Team teaching, co-teaching, collaborative teaching, and shared teaching are used interchangeably in the literature, but are not synonymous. The interpretation can vary according to the educational setting, the nature of the profession of those involved and the degree to which the planning and instruction is truly shared. It is important, therefore, to clearly define the concept in relation to the specific type of collaboration being studied, and not equating all forms of teaching that involve more than one teacher as "collaboration. The modern view of team teaching is that of an instructional team consisting of two or more professionals who teach a single group of students. A systematic review of experimental research on team teaching by De Weerdt et al. (2025) defined team teaching as a promising instructional approach that features multiple educators working together to deliver education. Their review, however, also highlighted the importance of better conceptualisation and study design for researching the effectiveness of team teaching. This is important because the result of the team teaching could be dependent on the quality of the collaboration of the two teachers, the division of the teaching load, the nature of the subject matter, and the model used for the team teaching.

Research on co-teaching and other collaborative models has also shown that collaborative forms of teaching are not a one-size-fits-all type of program and that there are multiple forms of collaborative teaching. To address this, Vembye et al. (2024) conducted a systematic review and meta-analysis of co-teaching and related collaborative instructional models, identifying the need to differentiate between the various types and contexts of collaborative teaching, after analyzing the findings from a vast number of treatment control studies. Recently, Du and Li (2025) also noted that a variety of co-teaching models are being implemented in educational contexts, including one-teach/one-assist, team-teaching, and other models. The results indicated that the extent of collaborative teaching effectiveness needs to be explored based on the collaborative teachers' organization and implementation of their teaching duties, not merely the number of teachers involved in teaching. The primary concept of team teaching is to work professionally toward a purpose. Teachers can use what they know, their experiences, pedagogical skills, and areas of expertise to plan and implement instruction. This partnership may afford students a variety of viewpoints on subject matter and allow teachers to share accountability for teaching and learning. But, effective team teaching goes beyond one teacher teaching as another is simply physically in the classroom. Recent studies have revealed that teachers need opportunities to grow their collaborative practices, negotiate the profession, coordinate teaching, and reflect on their collaborative work (Cochon-Drouet et al., 2023). Thus, the quality of communication, planning, understanding, and coordination among the collaborating teachers can be seen as crucial factors in the successful implementation of team teaching so it is essential to be able to have effective communication among teachers. Thus, the quality of communication, planning, understanding and coordination among collaborating teachers can be seen as crucial factors in the successful implementation of team teaching so effective communication among teachers is essential. In teacher education, team teaching is of special importance since teacher education programmes are not only expected to transmit academic knowledge, but are also expected to introduce prospective teachers to professional practices that they might face in their

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future career. However, if lecturers work together well in planning and presenting learning, students can be exposed to other professional attitudes and approaches in presenting academic content. Collaborative teaching can also serve as an example of how teachers interact with one another and practice with professionalism. However, these potential benefits must not be taken for granted. Existing systematic evidence suggests that the effectiveness of collaborative instructional arrangements is context and study dependent, thus highlighting the need for empirical evidence (De Weerdt et al., 2025; Vembye et al., 2024).

Concept of Jigsaw Strategy

Jigsaw is a structured cooperative learning model where students are given responsibility for learning specific parts of the instructional content and then, responsible for teaching or sharing that content with other members of their group. The strategy was first introduced in the 1970s by Elliot Aronson et al to enhance the learning and intergroup relationships of students from different groups (Aronson et al., 1978). The strategy has evolved over time and is one of the most recognized and widely studied cooperative learning strategies. The key to the Jigsaw strategy is positive interdependence. Students do their work in such a manner that every student has information or knowledge that is essential for another student in the group. As a result, the learning task success is partly dependent on the contribution of individual students. This is unlike typical group work, where some group members might do all the work, while others work barely at all. Jigsaw learning requires all students to deliver one section of the teaching material and hence ensures some level of accountability on top of group collaboration. The Jigsaw strategy has been the subject of a number of recent systematic reviews that offer important evidence about its impact on learning. In the systematic review and meta-analysis by Cochon Drouet et al. (2023) comprising 69 studies, the authors investigated the impact of Jigsaw on learning, motivation, social relations and self-esteem. There was substantial variation across studies in the outcomes reported, and factors like sample characteristics, classroom diversity and type of instructional content were identified as possible moderators of the effectiveness of the strategy. In a similar manner, Vives et al. (2025) performed a thorough systematic review of Jigsaw research that included studies conducted over 40 years. They concluded that while generally Jigsaw has been linked to positive learning outcomes, it has varying impacts on learning outcomes by subject matter, psychosocial outcomes and the context it is used in. The results suggest that the effectiveness of Jigsaw should be viewed as a structured teaching method that is to be implemented correctly and needs to be studied empirically in each context.

Research Objectives

The following particular goals were accomplished by the study:

1) Determine the difference in the post-test performance scores of students taught micro-teaching skills using the Team-teaching strategy and the conventional lecture method.
2) Determine the difference in the post-test performance scores of students taught micro-teaching skills using the Jigsaw strategy and the conventional lecture method.
3) Determine the difference in the post-test performance scores of students taught micro-teaching skills using the Team-teaching and Jigsaw strategies.
4) Determine the difference in the retention scores of students taught micro-teaching skills using the Team-teaching and Jigsaw strategies.

Research Questions

This paper addressed the following research questions

1. What is the difference in the post-test performance scores of students taught micro-teaching skills using the Team-teaching strategy and those taught using the conventional lecture method?

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2. What is the difference in the post-test performance scores of students taught micro-teaching skills using the Jigsaw strategy and those taught using the conventional lecture method?
3. What is the difference in the post-test performance scores of students taught micro-teaching skills using the Team-teaching and Jigsaw strategies?
4. What is the difference in the retention scores of students taught micro-teaching skills using the Team-teaching and Jigsaw strategies?

Null Hypotheses

The study developed and tested the following null hypotheses at the 0.05 level of significance:

$H0_1$ There is no significant difference between post-test performance scores of students taught micro-teaching skills using team-teaching technique and those taught using conventional lecture strategy.

$H0_2$ Significant difference does not exist between post-test performance scores of Students taught micro-teaching skills using jigsaw strategy and those taught using conventional lecture strategy.

$H0_3$ Post-test performance scores of students taught micro-teaching skills using team teaching technique does not significantly differ from post-test performance scores of students taught using jigsaw strategy.

$H0_4$ There is no significant difference between retention ability scores of students taught micro-teaching skills using team teaching technique and those taught using jigsaw strategy.

Research Methodology

The study adopted a quasi-experimental design involving two experimental groups and one control group. The population comprised NCE II students offering selected Social Studies combinations in the School of Arts and Social Sciences, Federal University of Education, while three purposively selected intact classes consisting of 195 students constituted the sample. Experimental Group I was taught using the team-teaching strategy, Experimental Group II received instruction through the Jigsaw strategy, while the Control Group was taught using the conventional lecture method. The use of intact classes was appropriate because individual students could not be randomly assigned without disrupting the existing academic arrangements. Data were collected using a researcher-developed instrument titled *Teaching Skills Performance and Retention Ability Test (TSPRAT)*, consisting of 40 multiple-choice items with four response options. The instrument was subjected to face and content validation by relevant experts and pilot-tested on students with similar characteristics to the study participants, producing a reliability coefficient of 0.83. The treatment lasted six weeks, after which the instrument was administered immediately to determine students' performance and re-administered two weeks later to assess retention of the learned content. The research questions were answered using mean and standard deviation, while the four null hypotheses were tested using independent-samples t-test at the 0.05 level of significance. The independent-samples t-test was considered appropriate because each hypothesis involved a comparison between two independent groups.

Presentation of Results

The four null hypotheses formulated for the study were tested at the 0.05 level of significance. The inferential analyses were conducted to determine whether the observed differences in students' post-test performance and retention scores across the instructional groups were statistically significant. The results are presented in Tables 1–4.

$H0_1$: There is no significant difference between the post-test performance scores of students taught micro-teaching skills using the Team-teaching strategy and those taught using the conventional lecture method at the Federal University of Education, Zaria.

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Table 1: Independent-samples t-test of the post-test performance scores of students taught micro-teaching skills using the Team-teaching strategy and the conventional lecture method

Variable	N	Mean	SD	df	t-cal.	Sig. (2-tailed)	Decision
Team-teaching	65	24.73	2.92	133	14.62	<.001	Sig.
Conventional	70	17.18	3.07				

Source: (Field Survey, 2026)

Table 1 presents the result of the independent-samples t-test comparing the post-test performance scores of students taught micro-teaching skills using the Team-teaching strategy and those taught using the conventional lecture method. Students in the Team-teaching group obtained a higher mean score (M = 24.73, SD = 2.92) than those in the conventional lecture group (M = 17.18, SD = 3.07). The calculated t-value of 14.62 with 133 degrees of freedom was statistically significant at the 0.05 level ($p < .001$). Therefore, the null hypothesis was rejected. This indicates that there was a statistically significant difference in the post-test performance scores of the two groups in favour of the Team-teaching group.

$H0_2$: There is no significant difference between the post-test performance scores of students taught micro-teaching skills using the Jigsaw strategy and those taught using the conventional lecture method at the Federal University of Education, Zaria.

Table 2: Independent-samples t-test of the post-test performance scores of students taught micro-teaching skills using the Jigsaw strategy and the conventional lecture method

Variable	N	Mean	SD	Df	t-cal.	Sig.	Decision
Jigsaw	60	24.83	2.30	128	18.53	< .001	Sig.
Post-test Conventional	70	16.03	3.00				

Source: (Field Survey, 2026)

Table 2 presents the result of the independent-samples t-test comparing the post-test performance scores of students taught micro-teaching skills using the Jigsaw strategy and those taught using the conventional lecture method. Students taught using the Jigsaw strategy obtained a higher mean score (M = 24.83, SD = 2.30) than those taught using the conventional lecture method (M = 16.03, SD = 3.00). The calculated t-value of 18.53 with 128 degrees of freedom was statistically significant at the 0.05 level ($p < .001$). Therefore, the null hypothesis was rejected. This indicates that there was a statistically significant difference in the post-test performance scores of the two groups in favour of the Jigsaw strategy.

H_{03}: There is no significant difference between the post-test performance scores of students taught micro-teaching skills using the Team-teaching strategy and those taught using the Jigsaw strategy at the Federal University of Education, Zaria.

Table 3: Independent-samples t-test of the post-test performance scores of students taught micro-teaching skills using the Team-teaching and Jigsaw strategies

Variable	N	Mean	SD	Df	t-cal.	Sig. (2-tailed)	Decision
Team-teaching	65	24.73	2.91	123	-0.21	.832	Not. Sig.

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	60	24.83	2.30
Jigsaw			

Source: (Field Survey, 2026)

Table 3 presents the result of the independent-samples t-test comparing the post-test performance scores of students taught micro-teaching skills using the Team-teaching and Jigsaw strategies. Students taught using the Jigsaw strategy obtained a mean score of 24.83 (SD = 2.30), while those taught using the Team-teaching strategy obtained a mean score of 24.73 (SD = 2.91). The calculated t-value of -0.21 with 123 degrees of freedom was not statistically significant at the 0.05 level (p = .832). Therefore, the null hypothesis was not rejected. This indicates that the study found no statistically significant difference between the post-test performance scores of students taught using the Team-teaching and Jigsaw strategies.

$H0_4$: There is no significant difference between the retention test scores of students taught micro-teaching skills using the Team-teaching and Jigsaw strategies at the Federal University of Education, Zaria.

Table 4: Independent-samples t-test of the retention test scores of students taught micro-teaching skills using the Team-teaching and Jigsaw strategies

Variable	N	Mean	SD	df	t-cal.	Sig. (2-tailed)	Decision
Team-teaching	65	24.66	2.30	123	-0.29	.775	Not Sig.
Jigsaw	60	24.75	0.81				

Source: (Field Survey, 2026)

Table 4 presents the result of the independent-samples t-test comparing the retention test scores of students taught micro-teaching skills using the Team-teaching and Jigsaw strategies. Students taught using the Jigsaw strategy obtained a mean retention score of 24.75 (SD = 0.81), while those taught using the Team-teaching strategy obtained a mean score of 24.66 (SD = 2.30). The calculated t-value of -0.29 with 123 degrees of freedom was not statistically significant at the 0.05 level (p = .775). Therefore, the null hypothesis was not rejected. This indicates that the study found no statistically significant difference between the retention test scores of students taught using the Team-teaching and Jigsaw strategies after the specified retention interval.

Discussion of Findings

The results of the present study indicated that there was a statistically significant difference between the students' post-test performance scores of the students taught with micro-teaching skills based on the Team-teaching strategy and those taught using conventional lecture method in favour of the group of students taught with micro-teaching skills ($p < .001$). This discovery implies that a collaborative teaching of two or more lecturers may offer more opportunities for explanation, demonstration, clarification, questioning, and instructional support for students than traditional teaching by one lecturer. When instruction is divided into micro-teaching skills, in which students are expected to learn and use various skills of teaching, the presence of complementary teaching perspectives could have helped the students exposed to Team-teaching to perform better. This discovery comes on the heels of a growing volume of evidence that collaborative teaching partnerships yield positive learning outcomes when they are well designed and executed. In a systematic review and meta-analysis of the research on co-teaching and related collaborative teaching models, Vembye

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et al. (2024) analyzed a large number of treatment-control studies and found evidence of the positive effects of collaborative teaching arrangements on students' academic achievement; however, the size of the effect may vary depending on certain contextual and implementation factors. Likewise, recent experimental research in the field of Team-teaching has shown that students may have better learning outcomes in team-taught classrooms than in classrooms taught by individual teachers, but the magnitude of the difference may not always be large and may depend on classroom contexts. The results of the present finding, however, do not necessarily imply that the implementation of team-teaching always yields better learning results. The results of a recent meta-analysis conducted by Stefanidis et al. (2023) reviewed academic outcomes of co-taught and solo-taught classrooms were inconclusive and inconsistent in terms of the superiority of co-teaching across all settings. The findings may reflect the effects of variation in student characteristics, the purpose of co-teaching, the manner in which teachers collaborate, the quality of the instruction being delivered, and the way group comparability is accomplished. Therefore, the results of the present study showed that the Team-teaching method was superior to the traditional lecture method, but the result should be interpreted in the context of instructional and institutional conditions in which the study was implemented. The study also found that the post-test performance of the students who were taught micro-teaching skills with the help of Jigsaw strategy had statistical significance difference from the students who were taught using the conventional lecture method in favour of the Jigsaw strategy ($p < .001$). The mean performance score of students taught under the Jigsaw strategy was significantly higher than the mean performance score of the students who were taught by the conventional lecture method. This could relate to the active learning processes included in the Jigsaw strategy. Students will be expected to learn parts of the instruction, engage with experts in expert groups, know the instruction they are assigned, and then present the instruction to their home groups. These processes can foster active involvement, individual accountability, positive interdependence, discussion, elaboration, and peer teaching. The recent evidence about the educational outcomes of the Jigsaw method supports the present finding. In a systematic review and meta-analysis of 69 studies exploring the impact of the Jigsaw method on students' performance, Cochon Drouet et al. (2023) found that the strategy had a positive overall impact. They conducted a meta-analysis of 43 studies on achievement and discovered that overall, the impact was positive and significant, indicating that Jigsaw can be helpful in the academic learning process when implemented properly. The results of the present study are in line with evidence that structured cooperative learning offers more active learning opportunities for students to process, discuss and explain learning materials than the teacher-centred learning.

However, there is also recent evidence that the effectiveness of the Jigsaw strategy is not consistent in all educational settings. Cochon Drouet et al. (2023) discovered that there was great variation in the studies reviewed and that the impact of Jigsaw can differ depending on the characteristics of the learners, the content of the course, and the composition of classes, sample size, and how the strategy was used. Similarly, Vives et al. (2025), in their latest systematic review on the Jigsaw over the last 40 years, found that the Jigsaw strategy has positive effects overall but these are subject dependent and depend on the measure of psychosocial outcomes. Further, these mixed outcomes are significant in that they indicate that the positive outcome found in the present study cannot be exclusively attributed to the name "Jigsaw" but also to the quality of implementation and the appropriateness of the strategy for teaching micro-teaching skills. The third finding indicated that the students' performance scores in the post test were not significantly different ($p = .832$) between the students who learned micro-teaching skills in the team-teaching strategy and the students who learned micro-

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teaching skills in the jigsaw strategy. The mean score in the Jigsaw group was higher than the mean score in the Team-teaching group, but the difference was not significant. This result suggests that the performance of students' micro-teaching skills was about the same under both the instructional strategies in the present study. One possible reason for this similarity is that both strategies are designed to increase interaction and engagement with instructional material and are not the traditional lecture approach. Team-teaching encourages cooperation between teachers and could lead to students experiencing more than one explanation, demonstration, and approach to teaching. The Jigsaw approach, on the other hand, fosters student interaction through discussion with peers, individual accountability and shared building of understanding. The mechanisms are different, but both methods could have motivated students to be more involved in their learning, resulting in similar learning outcomes.

This is also in line with recent reviews that have found that the effectiveness of both collaborative teaching and cooperative learning strategies is context and implementation dependent. The authors of the systematic review and meta-analysis (Vembye et al., 2024) pointed to a number of factors which affect the outcomes of co-teaching practices. Likewise, Cochon Drouet et al. (2023) and Vives et al. (2025) showed that there are significant study-to-study and context-to-context differences in Jigsaw outcomes. Consequently, the results of the present study do not suggest that Team-teaching and Jigsaw are different in their effectiveness to promote students' learning of the selected micro-teaching content, but it does suggest that both strategies are equally effective.

The fourth finding indicated that the retention test scores of the students who used the micro-teaching skills with the Team-teaching and Jigsaw strategies were not significantly different ($p = .775$). The Jigsaw group did not achieve a significantly higher mean retention score than the Team-teaching group, but it did achieve a slightly better score. Thus, the finding suggests that both the instructional strategies were not significantly better than each other for students' retention of the learned micro-teaching content during the retention interval used in the study. This outcome could be due to the level of active learning opportunities provided by both strategies. Retention can be achieved through multiple models and explanations of a concept (team teaching) and multiple discussions, peer explanations, elaboration, and active processing of instructional content (Jigsaw). Both groups were presented with instructional techniques that could have asked for more active learning than passive listening, which could have led to similar retention results. However, the finding must be taken with a pinch of salt as recent studies by Jigsaw have revealed that contextual factors and the non-uniformity of findings in studies impact on the educational outcomes. Cochon Drouet et al. (2023) found that the impact of Jigsaw varied significantly as a function of the academic and the psychosocial variables studied, and Vives et al. (2025) reported that there was significant variation in impact according to academic and psychosocial variables studied. These observations indicate that the effectiveness of cooperative and collaborative instructional strategies for retention might vary with the type of content taught, treatment length, quality of implementation, and student participation in content and the time elapsing between instruction and the retention assessment. The present finding should, therefore, be interpreted as evidence that there are no significant differences between the two interventions in retention outcomes within the particular two-week retention period examined in the present study and not as a finding that the two strategies will necessarily produce the same retention outcomes in all educational contexts.

Conclusion

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Based on the results obtained from the findings of the study, it was concluded that the Team-teaching and the Jigsaw strategies were more effective than the traditional lecture strategy in enhancing the performance of the students in the micro-teaching skills in the Federal University of Education, Zaria. There was a significant difference between both Team-teaching and Jigsaw instructional strategies and the conventional lecture method in terms of the post-test performance scores of their students. But, the performance difference between students taught with the Team-teaching strategy and students taught with the Jigsaw strategy was not statistically significant, showing that the two instructional strategies yielded similar performance results under the conditions of the study. The study also found that, Team-teaching and Jigsaw strategies yielded similar retention results of the students after two weeks retention period. The mean scores for retention for the Jigsaw group were slightly higher, but this difference was not significant between the two groups. Thus, there was no statistically significant difference between Team-teaching and Jigsaw and in students' retention of the learned content of micro-teaching within the period investigated. In general, the study concluded that both teaching methods are presentable alternatives to the traditional lecture method for teaching micro-teaching skills and that their successful application should consider the content of the learning material, learning goals, staff, class characteristics, and proper implementation conditions.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. Lecturers who teach micro-teaching and related education courses should be encouraged to use Team-teaching or Jigsaw teaching in the classroom, especially in the process of teaching and learning that needs students to be active, interactive, display, discuss and cooperate.
2. The Management of Federal University of Education, Zaria should arrange team training sessions, seminars and professional development sessions for lecturers from time-to-time on effective team teaching and jigsaw strategy.
3. The choice of either of the team-teaching or the jigsaw strategy to use must depend on the nature of the content and instructional context of the course to be taught, and not depend on the notion of either being superior or inferior to the other.
4. Education authorities and lecturers should promote instructional approaches that encourage active participation and collaboration while retaining the conventional lecture method as a complementary instructional approach where necessary.

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Leveraging Artificial Intelligence in Enhancing Worldwide Science, Technology, Engineering and Mathematics (STEM) Education

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Abstract
Artificial intelligence is rapidly transforming education and presents opportunities for improving the quality, accessibility and inclusivity of STEM education around the globe. This conceptual paper examines the potential of AI to address persistent challenges in global STEM education. The paper explores major applications of AI in education including adaptive and personalized learning, intelligent tutoring systems, learning analytics, and teacher augmentation. Based on literature STEM education and educational technology an AI-STEM Global Enhancement Framework is proposed comprising of four core pillars: adaptive and personalized learning, intelligent tutoring and support, Smart assessment and analytics and teacher augmentation. This framework is anchored by the cross-cutting themes of equity, inclusivity, ethics, and global collaboration. The paper further examines challenges associated with AI integration in STEM education and suggests ways of mitigating these challenges. The paper concludes that AI should be actively integrated into STEM education and recommends a human-centred, ethical approach to its use in other to promote equitable and quality STEM education.
Keywords: Artificial Intelligence, STEM Education, Personalized Learning, Global Education.

Introduction
Education is an integral tool for societal building. According to Ayua et al. (2026a) Education is a fundamental instrument for human development, social stability, economic participation and global transformation. This explicates that an educated person can be functional suited in the society if it is wholistically implemented. It is a global phenomenon that can phased out boundaries. Global education refers to learning systems designed to overcome the barriers of geography, epistemology and institution to build competencies that allow engagement in interconnected global communities (Zaman, 2020). It therefore means that educational curricula maybe rich in accordance with the inspiration, needs or demands of the global society. Ayua and Taangahar (2024); Ayua (2019) posits

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that curriculum could always adapt to suit modern trends and paradigm shifts and STEM education is crucial for fostering the skills required for Sustainable Development Goals (SDGs) to be achieved by 2030 and beyond. This has become a world question whether technology can be a solution to STEM education, since the world has become a global village being interconnected through technology?

STEM is an approach to learning that connects four fields of science instead of teaching them separately. Science, which has to do with understanding the natural world through Biology, Chemistry, Physics and Earth Science. Technology, which is using scientific knowledge to create tools like Artificial Intelligence (AI) apps. Engineering which deals with designing and building solutions including civil, mechanical and electrical software. Mathematics that is the language for all of it, for example data analytics, logic and problem solving. These can be described as the centre for scientific discovery and innovation constituting a framework for global innovation and technological advancement. Fajrina and Ahda (2020) add that STEM education is an approach to learning that integrates elements of science, Technology, Engineering and Mathematics in the learning process and that each discipline is insufficient on its own as they cannot do without the other. However, the holistic integration of STEM education for 21st-century skills like critical and creative thinking skills, resilience, collaboration and problem-solving skills for everyday life is worrisome. Ayua (2019) confirms that one of the basic challenges in global STEM education is the limited resources available. Though the advancement of technology can be a solution to STEM education since it relies heavily on educational technology to create concepts, ideas and principles. One of these technologies is Artificial Intelligence (AI).

GenAI is AI which can create new stuff instead of just analysing or classifying old stuff. While Artificial intelligence (AI) is a complex evolution of technological innovation that is changing the global landscape (Terhemba et al. 2026; Ayua & Kwagh, 2026; Jomen et al., 2026). Its birth (invention) and rebirth (innovation) and it can be traced to a parallel advancement in STEM facilitated by STEM education. AI is a computer program that is able to learn from existing information and adapt behaviour to function efficiently in changing environments. These large language models can be able to show adaptive behaviour which is the hallmark of intelligence. Luckin et al (2016) asserts that AI is a computer system designed to perform tasks that typically require human intelligence such as visual perception, speech recognition, decision-making and language translation. It means that it can see and hear, understand and use language, create new things (GenAI), predict and decide, reason and solve problems, control and automate physical world, and amplify human work. Ayua et al (2026c) Kaplan and Haenlein (2019) see AI as systems with the ability to correctly interpret data, to learn from such data, and to use that knowledge to achieve specific goals and tasks. AI is able to adapt to the needs of learners and offer learning experiences that are learner-specific (Terhemba et al., 2026; Ayua et al., 2026b). This feature and application of AI in education makes it a valuable resource in Science, Technology, Engineering and Mathematics (STEM) education in providing personalized learning experiences that meet the specific needs of learners.

The fourth industrial revolution is characterized by the emergence of technologies, machines and computer programs such as artificial intelligence, robotics and the internet. This has intensified the need and global demand for STEM skills, knowledge and competencies. This is because modern technological innovations depend on scientific knowledge, logical reasoning, engineering skills and technological competency. It is therefore imperative to revolutionize and improve STEM education with techno-pedagogical shift like artificial intelligence.

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Statement of the Problem

STEM education in ideal situation is supposed to make individuals skilful for action of no poverty, zero hunger, good health and wellbeing, quality education, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, and partnership for the goals. However, there is a yawning gap between policy and practice for a wholistic implementation of STEM education. The fourth industrial revolution has significantly increased the global demand for knowledge and skills in STEM (Ayua, 2019; Ayua et al., 2022) and increasing application of artificial intelligence, machine programming and other emerging technologies require individuals who can think critically, creatively and apply scientific knowledge through technology and engineering. With this demand, the quality STEM education remains poor by pedagogy. This may include unequal access to STEM learning and inadequacy of proper teaching and learning resources especially in rural and disadvantaged communities (Aya et al., 2026a; Ayua et al., 2026d; Jaya et al., 2026). Also, the inadequacy of qualified and competent teachers in STEM related disciplines challenges the quality of knowledge and skills they are able to deliver. The unavailability of quality STEM teaching resources results in teacher centred teaching which promotes rote memorization. This creates a pressing need to rethink STEM teaching through techno-pedagogical approaches that promote active learning, equity, and global inclusivity in STEM education (Terhemba & Ayua, 2026).

Purpose of the Study

The purpose of this paper is to conceptualize the pedagogical use of AI in enhancing teaching, learning and assessment in STEM globally.

Significance of the Study

In line with Sustainable Development Goal 4, this paper will ensure access to inclusive and equitable quality education, promoting lifelong learning for all. It will also produce individuals equip for global competitiveness.

Scope of the Study

The paper is conceptual with worldwide focus drawing from both developed and developing contexts.

Conceptual Clarifications

STEM education in global context, Artificial intelligence in education and Rationale and discussed

STEM Education in Global Context

STEM education is an educational approach that integrates Science, Technology, Engineering and Mathematics. According to the United Nations Educational, Scientific and Cultural Organization ([UNESCO], 2026) STEM education is an interdisciplinary approach that equips learners with scientific knowledge, critical thinking, creativity, problem solving and innovation skills needed to address real-world challenges and participate effectively in a technology driven society. The global nature of STEM education is anchored on the premise that its knowledge and skills are globally relevant and the need for scientific, technological, engineering and mathematical knowledge is not limited to one country or region. STEM education is driven by worldwide advancements in knowledge and discovery.

Artificial Intelligence in Education

Artificial intelligence in education is an emerging interdisciplinary field that applies AI technologies in education to transform and promote the instructional and learning design, process and assessment (Chen et al., 2020). Artificial intelligence in education refers to the adoption of AI systems

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such as AI Tutors, adaptive learning systems, generative AI and learning analytics to support the education process such as teaching, learning and assessment. According to Albadarin et al. (2024) educational technology has evolved into AI systems with capacity to make significant advancements in learning, instructional methods as well as supporting administrative tasks. AI systems are capable of delivering learning experiences that meet individual learning needs (Jomen & Ayua, 2026).

The Rationale

Artificial intelligence is critical for scaling and delivering quality STEM education because it is capable of providing personalized instructions and quality learning resources that bridge the gap from abstract to concrete learning. AI can also deliver immediate feedback and support the assessment process of learners in STEM.

Literature Review/Theoretical Framework

Global trends of AI in Education, applications of AI in science, Technology, Engineering, and Mathematics, Benefits, Challenges and theoretical base are hereby reviewed.

Global Trends in AI in Education

Global trends in AI inclusion in education from 2020-2026 indicates a shift towards the widespread adoption of generative AI, AI Chatbots and personalized learning systems. AI can be used to personalize learning, support teachers in planning and delivering learning experiences and automate educational task such as grading assessment (Organization for Economic Co-operation and Development [OECD], 2025). As a result, global education systems are emphasizing digital literacy among teachers and students. However, there is call for a human-centred approach in the use and adoption of Generative AI in education (UNESCO, 2025).

Applications of AI in Science, Technology, Engineering and Mathematics

The ability of AI to perform numerous tasks has made it a useful tool with applications cutting across STEM disciplines. According to Terhemba and Ayua (2026) a vital merit of AI in STEM education is the ability to promote personalized learning, correct misconceptions, offer additional explanations and offer immediate feedback on student progress. These applications are vital in STEM fields. In Science AI is applied to analyse large amounts of data, scientific modelling, simulations and pattern recognition. In the field of technology, AI applications include robotics, software development, cyber-security and the development of intelligent data systems. Applications of AI in engineering are geared towards improving the efficiency and accuracy of engineering processes through system optimization, process automation, fault detection and predictive maintenance. The field of Mathematics has experienced improvement with AI through mathematical modelling, statistical analysis, coding and mathematical prediction models (Xu & Ouyang, 2022).

Benefits

The benefits and applications of AI in STEM education is yet under-explored. Improvements in AI programming directly translates to an improved educational experience as far as AI in concerned as represented in figure 1.

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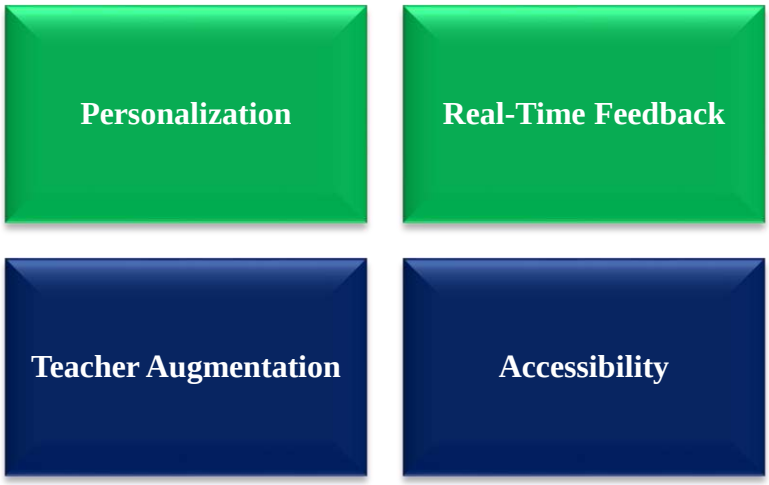


Figure 1: Schematic Representation of AI Benefits

As shown in Figure 1, AI systems are capable of diagnosing and accommodating different learning needs and abilities of students and to personalize learning experiences to meet individual student needs. This feature improves the quality and efficiency of STEM education by improving student participation and comprehension. AI systems maybe capable of delivering assessment feedback in real-time which helps to augment and support learning by promoting self-correction, increasing learner engagement and participation and strengthening understanding (Ayua et al., 2026b). The insufficiency of adequately trained and qualified teachers in STEM fields has been a major factor challenging the global quality of STEM education. AI systems can be used to augment and support teaching and learning. This is especially relevant where the student/teacher ratio is high. The unique capabilities of AI systems improve accessibility and creates inclusive opportunities for participation in STEM education by reducing barriers associated with geographical location, language, limited instructional resources and difference in students learning needs.

Challenges

While AI possess many benefits, in STEM education there are lingering challenges associated with its inclusion as shown in Figure 2:

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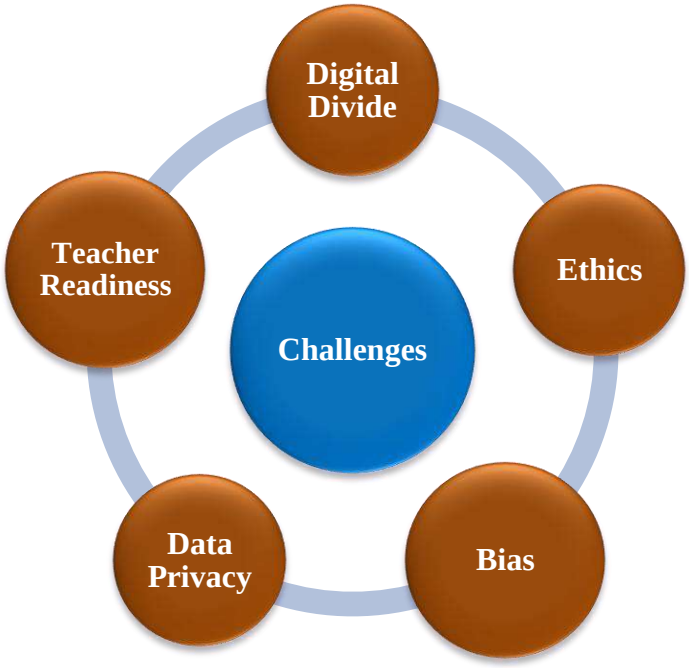


Figure 2: Challenges of AI in STEM Education

As presented in Figure 2, in developing countries like Nigeria among others, there is lack of proper access to digital devices as shown in Figure 2, reliable internet services, electricity and an inadequacy of the digital competency to operate AI systems especially in rural areas. This presents a challenge that confronts the successful and efficient implementation of AI in STEM education. The ethical concerns can limit AI inclusion in STEM education because issues surrounding transparency, academic integrity and responsible use may undermine trust, equity and the safe adoption of AI technologies. AI biased algorithms and data sets may reproduce existing inequalities such as gender-based inequality, resulting in unfair learning opportunities and educational experiences for certain group of students. The concerns bordering on the collection, storage, sharing and misuse of students' personal data and academic records can pose security risks and reduce trust in AI-supported learning. Teacher readiness can also hinder the effective and responsible inclusion of AI in STEM education when teachers lack the technological knowledge, pedagogical skills, and positive attitude towards AI supported learning.

Technological Pedagogical Content Knowledge (TPACK) Framework

The TPACK framework is a theoretical framework developed by Mishra and Koehler (2006). The framework explains the knowledge teachers need to integrate technology effectively into teaching. The framework consists of three forms of knowledge relevant for effective and efficient teaching as presented in Figure 3.

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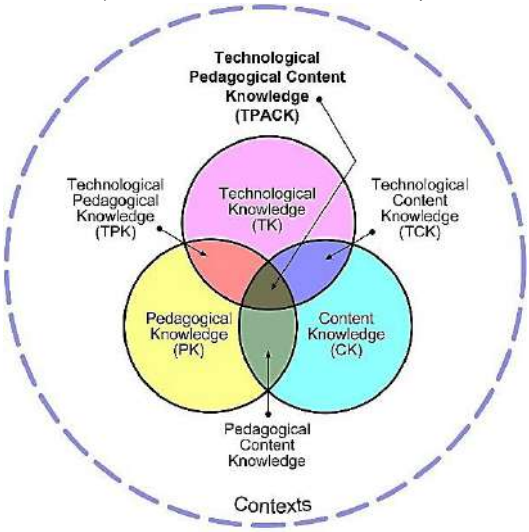


Figure 3: The Schematic Representation of TPACK Framework (Mishra & Koehler, 2006)

As show in Figure 3 Technology Knowledge (TK) is being knowledgeable about varieties of technological tools ranging from the basic, such as pencil and paper, to the most sophisticated, such as the world wide web, digital video, interactive white board and computer programs. Content Knowledge (CK) is the information about a specific topic that could be covered in a course or lesson. Educators therefore need background knowledge on the subjects they planned to cover and an understanding of how different types of knowledge are taught. Pedagogical Knowledge (PK) includes skill the in the classroom administration, students' evaluation, lesson planning and students naming. Pedagogical Content Knowledge (PCK) is the subjects' matter; experts gain for instructional purpose. Knowledge of both the subject matter and pedagogical practices necessary for effective teaching is PCK and its subject specific.

Technological Content Knowledge (TCK) is being familiar with the ways in which modern technologies can be used to create alternative representations of existing information. It means that educators can appreciate the power of technological tool such AI to change their students' approaches to learning withing a subject area. Technological Pedagogical Knowledge (TPK) can describe educators who are well versed in the way in which modern technology can be applied to the classroom and who recognise that these tools have the potential to alter traditional or conventional pedagogy. Technological Pedagogical Content Knowledge (TPACK) for effective teaching in any subject area, there can be a firm grasp of the educational content of technical tools at teacher's disposal. Teachers can have an intrinsic awareness of the relationship between the three pillars of knowledge, as evidenced by their utilization of successful pedagogical practice and technology resources in the STEM classroom for development of students' 21st-century skills (CK, PK, TK). The TPACK Framework provides a theoretical foundation for the integration of AI in STEM education by emphasizing the intersection of technological, content and pedagogical knowledge. This suggests that effective AI-supported STEM education requires teachers not only to have content and pedagogical knowledge but to be competent in handling technologies such as AI to support STEM instruction.

The AI-STEM Global Enhancement Framework

The Rationale for the framework, core pillars, cross-cutting themes and how the framework will enhance worldwide STEM education, are discussed as follows:

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Rationale for the framework

The rapid development of AI systems has created new and endless possibilities for addressing persistent challenges in STEM education. The AI-STEM Global Enhancement Framework is for explaining how AI can be integrated into STEM education to improve learning outcomes and promote equitable access to quality STEM education across geographical boundaries. The framework conceptualizes AI integration around four pillars as shown in Figure 4. These core pillars of AI-STEM Global Enhancement framework are held together and operate within the cross-cutting principles of equity, inclusivity, ethics and global collaboration.

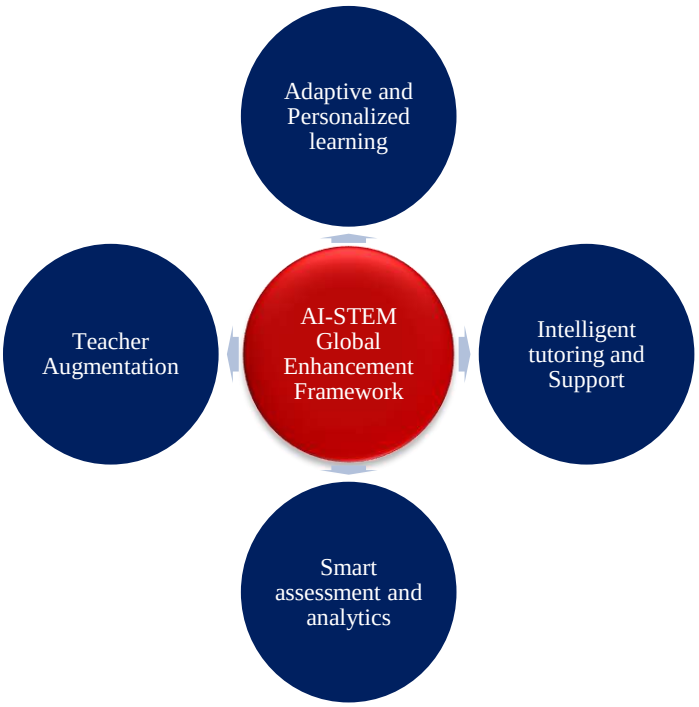


Figure 4: AI-STEM Global Enhancement Framework

As show in Figure 4, adaptive and personalized learning for traditional classroom instruction often presents the same learning activities to all categories of students despite their difference in prior knowledge, learning pace, attitude and learning abilities. AI can address this pedagogical challenge by modifying learning experiences according to the individual characteristics, needs and learning abilities of learners (Ayua et al., 2026b; Parsakia, 2023). Within STEM education, adaptive AI systems can diagnose student learning needs and provide additional instruction, examples, simulations or practice activities. Learners who show higher order cognitive abilities can be exposed to more complex problems. This creates differentiated learning experiences for learners at their appropriate learning pace and moves STEM education towards students centred approach. Intelligent tutoring and support show that AI systems have the ability to provide learners with instructional assistance, explanations, guidance and feedback at any day and time during the learning process. AI based intelligent tutoring systems can simulate some functions traditionally performed by human teachers such as responding to questions. This pillar is important because STEM learning involves abstract concepts and complex problem-solving processes. This pillar emphasizes the ability of AI to augment teaching and learning at any point along the learning process.

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Smart assessment and analytics AI systems can be used for the collection, analysis and interpretation of learner assessment data to improve teaching and learning. AI systems can analyse student assessment and identify patterns of errors, misconceptions and provide immediate feedback. In STEM education, learners are prone to misconceptions on scientific principles or mathematical procedures. AI can diagnose learners through assessment to provide information about these misconceptions. The teacher can then modify instruction to provide an intervention. Teacher augmentation represents the use of AI to enhance and support teachers' instructional responsibilities. Teacher responsibilities such as lesson planning, preparation of instructional materials, assessment construction, and analysis of learner performance and academic development. In STEM education teachers may adopt AI to generate differentiated learning experiences, develop problem-solving activities, formulate assessment questions among others. It is important to emphasize that AI systems can only support and not replace the teacher (Terhemba & Ayua, 2026). Regarding the cross-cutting themes, equity can ensure that the benefits of AI supported STEM education are available to learners irrespective of geographical location, gender, socioeconomic status or disability. This framework will ensure equal access to STEM education. It will address existing biases and promote fairness across all categories of learners. Inclusivity may focus on designing AI-supported STEM learning activities that accommodate diverse needs, abilities and backgrounds of learners. AI can be utilized as a tool for enhancing the meaningful participation of learners despite the differences that exists between them. Ethics could do with the moral principles that guide the integration of AI in STEM education. The framework will be built on responsible use of AI to foster core academic and moral values of honesty, responsibility, integrity and data privacy (Ayua & Kwagh, 2026). The framework promotes a human centred approach to the use of AI where AI is used as a supportive tool and not to replace the teacher which borders on irresponsible use. Collaboration among educators, researchers, international organizations, educational institutions, governments and technology developers can facilitate the making of policies, the exchange of knowledge, pedagogical practices and digital resources. Such global collaboration is important for advancing equity in global STEM education in line with Sustainable Development Goal 4.

How the Framework could Enhance Worldwide STEM Education

The AI-STEM Global Enhancement Framework may enhance worldwide STEM education by providing an integrated approach through artificial intelligence which can improve the quality, accessibility, efficiency and inclusiveness of teaching and learning. Rather than viewing AI as a replacement for teachers, the framework can be a complementary technology that supports learners in learning and teachers in teaching. The framework promotes personalized STEM learning and expands access to quality all-round academic support. The framework also strengthens assessment and learning analytics and enhances teacher effectiveness. The work of teachers is often times very bulky for them to do and this can reduce teacher effectiveness and efficiency. AI systems can support teachers in carrying out several tasks at a time including lesson and assessment planning and sourcing for instructional materials. The framework provides an opportunity for access to quality STEM education across local, national and international boundaries.

Implications for Policy, Practice and Teacher Education

Curriculum integration, Teacher professional development for AI-Augmented pedagogy, Infrastructure and policy, and Global partnerships are discussed as presented in Figure 5.

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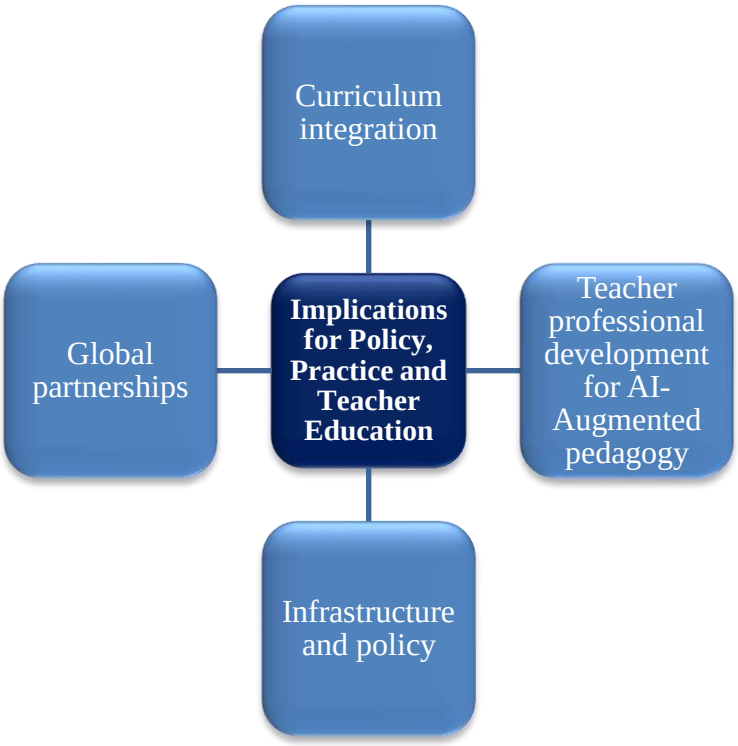


Figure 5: Schematic representation of Implications for Policy, Practice and Teacher Education

As presented in Figure 5**,** technological and digital skills are essential 21st-century skills. AI literacy can be integrated into STEM curriculum to equip learners with the knowledge and the required technological and digital skills in other to understand, use and responsibly interact with AI technologies. Teachers are the implementers of any curricular therefore, the successful implementation of AI in STEM education depends to a very large extent on teachers' competence in using AI technologies. Educational ministries and institutions may provide continuous professional development in technological and digital competency. Teacher educational programs can incorporate AI competency training alongside pedagogical and content knowledge training as well as the ethical use of these technologies. Adequate infrastructure is essential for successful integration of AI. This requires reliable internet services, electricity, digital devices, software programs and secure digital environments. Governments and educational institutions can invest adequate digital infrastructure in both rural and developing communities to ensure quality access to STEM education. Moreso, government can enact policies that guide responsible use of AI in STEM education. International collaboration could be established to enhance the adoption of AI in STEM education by allowing countries and educational institutions to share expertise knowledge, technological innovations and digital resources.

Mitigation Strategies AI-STEM Global Enhancement Framework Challenges

The full-scale implementation of the AI-STEM Global Enhancement Framework requires vast infrastructure such as reliable electricity, internet connectivity, digital devices, adaptive learning platforms and ICT facilities. These infrastructures mostly are unavailable especially in rural and developing areas, the cost implication of making them available is also very high. Difference in access to this infrastructure can create disparities between schools and learners in urban and rural regions. However, the low-cost digital tools can be a solution-based. AI integration can raise concerns

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bordering on ethical use, academic integrity, algorithmic bias and data security. These concerns can affect the efficiency of AI integration in STEM education. Therefore, Public-Private Partnership, Open Education Resource (OER) and Capacity building can help in effective practice of AI-STEM Global Enhancement Framework. Public-Private Partnerships can help governments, educational institutions and technology companies to work together and combine financial and technical resources. While the government provides policy direction and infrastructural support. Private organizations can provide other relevant support in terms of technological innovations and expertise. The Open Education Resource can reduce dependence on expensive educational material by making learning resources freely accessible for use, adaptation and distribution where permitted. AI systems can help adapt learning resources to learners needs, language and level. Teachers need training in technological and digital competence to ensure effective and ethical use of AI in STEM education.

Conclusion

Artificial Intelligence is an important component in modern day education with the potential to transform the teaching and learning of Science, Technology, Engineering and Mathematics. This submits that AI can contribute to enhancing the quality of STEM education by Supporting personalized learning and intelligent tutoring, Smart assessment, learning analytics and teacher augmentation through the AI-STEM Global Enhancement Framework. The AI-STEM Enhancement Framework provides an integrated model for understanding how AI can enhance STEM education globally through its four core pillars. The Framework is supported by the cross-cutting themes of equity, inclusivity, ethics and global collaboration. Despite its potential, the practice of the framework presents some challenges including inadequate infrastructure, algorithmic bias, ethical concerns among others. These challenges can be mitigated through government policies, teacher education programs and public-private partnership.

Call to Action

There is need for immediate action to improve the quality of global STEM education. The central challenge is how AI can be meaningfully and responsibly be integrated into teaching and learning. Concerned authorities and educational stakeholders therefore need to move towards practical practice.

Future Research Directions

Future research can move beyond conceptual discussions to empirical evidence on the effectiveness, sustainability and equity of AI-Supported STEM education.

Recommendations

The paper recommended among others that:

1. Policy Makers should develop clear national policies for AI in STEM education. These policies should address ethical concerns such as the responsible use of AI, data privacy and security, algorithmic bias, academic integrity and equity.
2. Governments and educational institutions should invest in the infrastructure required for effective AI integration. Reliable electricity, strong internet connection, digital devices and technical support particularly in rural and developing communities.
3. Teacher education institutions should integrate AI literacy and AI supported pedagogy into pre-service and in-service teacher education programs. Continuous professional development should equip STEM teachers with the technological, content and pedagogical competencies to effectively integrate AI in STEM instruction.

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4. Governments, educational institutions, technological organizations and international organizations should strengthen collaborative development to advance global education in STEM disciplines.

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Effect of Collaborative Learning Strategy on academic achievement in Vocational Subjects among Primary School Pupils in Uvwie, Delta State, Nigeria

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Abstract

The study investigated the role of collaborative learning on pupils academic achievement in vocational subjects in uvwie local government area, Nigeria. Two research questions and two null hypotheses guide the study. The study adopted a quasi experimental research design for both treatment and control groups. The population of the study consists of 8,932 pupils of the 21 primary schools in uvwie local government area in Delta state. As reported by basic education board, Asaba , 2025, from this population, a sample size of 136 pupils were selected using purposive sampling. Purposive sampling was also used to select the two schools with specific criteria relevant to the study, characteristics and their similarity in academic performance, size, and accessibility. These criteria were essential to ensure a fair and meaningful comparison between the experimental and control groups. The intact class of 68 pupils were used for the study. One school served as the experimental group, and the other served as the control group. The instrument for data collection for the study was agriculture science achievement Test. The items of this instrument were developed by the researchers from the agriculture science content in primary five. The instrument consisted of 10 Multiple-choice questions based on primary school curriculum content for agriculture science. The instrument was validated by experts in education and pilot tested to ensure reliability. The experimental group received the treatment. while the control group continued with conventional instruction. Data collected were analyzed using descriptive statistics (mean and standard deviation) and inferential statistics (e.g., t-test) to determine the significance of the difference between the pre-test and post-test scores of both groups. The results revealed that collaborative learning technique has a strong positive effect post – test on pupils academic performance in vocational subjects in primary school. The study also shown that pupils who are expose to collaborative learning perform better than their counterpart who learnt vocational subjects using conventional method in primary. Therefore, the study recommended among others that Local education authority and heads of primary schools should organize training for primary schools teachers on the use collaborative learning technique. Primary schools pupils should be exposed by teachers in the use of collaborative learning of vocational subjects in the classroom.

Keywords: collaborative learning technique, vocational subjects, academic performance and primary school

Introduction

Primary education is the education given in an institution for children aged 6 to 11 plus. It is a type of education children receive at early stage of life before secondary education. This education is the first level of education and it is a foundation upon which other levels of education are built. Primary education also offers diversify curricular that provide diverse basic knowledge and manipulative skills that will enable the child to function effectively in the society within the limits of the child's

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capability. The broad goals of primary education include; Inculcate permanent literacy and numeracy and the ability to communicate effectively, lay a sound basis for scientific and reflective thinking, give citizenship education as a basis for effective participation in and contribution to life of the society, mould the character and develop sound attitudes and morals in the child, develop in the child ability to adapt to his or her changing environment, give the child opportunities for developing manipulative skills that will enable him or her to function effectively in the society within the limits of his or her capacity and Provide the child with basic tools for further educational advancement, including preparation for trades and crafts of the locality. In order to achieve the goals of primary education, educators need to integrate vocational subjects into the primary school curriculum as part of the government's effort to equip pupils with practical skills that are crucial for their personal and professional development.

Vocational subjects, also known as Technical and Vocational Education and Training which could be seen as educational programs that focus on preparing learners for specific occupations or trades by providing them with practical skills and knowledge. These subjects typically involve hands-on training, application of theoretical knowledge, and development of industry-specific competencies. Ojimba (2012) described Vocational and Technical Education as forms of education whose primary aim is to prepare persons for recognized occupation and this encompasses field of study (agricultural education, fine and applied arts education, business education and vocational trades in soap making, hairdressing, computer training among others). The vocational subjects in primary school in Nigeria at present are agriculture, home economics, carpentry, and tailoring which provide pupils with opportunities to learn valuable skills that are directly applicable in real-world scenarios. Despite the importance of these subjects, the teaching and learning process in Nigerian primary schools face several challenges which include lack of technical Know- how, overcrowded classrooms, limited resources, and inadequate training for teachers. One of the strategies that may enhance the learning experience and improve academic performance in these subjects is collaborative learning.

Collaborative learning cannot be applied through verbal instruction only. Collaborative learning refers to a learning method in which learners at various performance levels work together in small groups toward a common goal. The learners are responsible for one another's learning as well as their own. Thus, the success of one learner helps other leaners to be successful (Slavin in Kulo 2021). Collaborative learning is a teaching and learning strategy that involves two or more learners in a group who have different abilities and thoughts and are jointly engaged in a learning process (Dewi et al., 2021; Hadwin et al., 2018; Warsah et al., 2021). This approach has gained significance in contemporary education systems globally due to its potential to improve learners engagement, comprehension and academic performance. collaborative learning has numerous benefits for learners' learning experiences. This approach enables learners to develop critical thinking, cooperation, communication, and other essential skills while learning the course material selected by their teacher (Hursen, 2021). Researchers have discovered that collaborative learning has significant impact in learners academic performance. Sulaiman and Shahrill (2015), from the research, when they discovered that collaborative learning demonstrated positive impacts on students performance where students engaged in learning activities while being able to develop teamwork skills. Mallika, Shorouk and Cheong (2023) collaborative learning has been known to provide students with a sense of satisfaction as they are involved in decision-making and problem - solving. This helps to increase students confidence and interest in challenging subjects, leading to improved academic performance. It is against this back drop that the researchers intend to

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investigate the role of collaborative learning on pupils academic achievement in vocational subjects in uvwie local government area of delta state, Nigeria.

Statement of the problem

Despite the use of collaborative learning in the primary school which has significant impact on learners, the learners has still facing issues in the application of collaborative learning in vocational subjects. These vocational subjects taught in the primary still lack the use of collaborative learning for non inclusion of the subjects in the primary school curriculum as shown in that of the secondary school curricula. Traditional teaching strategies, often dominated by rote learning and minimal student interaction, may not adequately cater to the learning needs of pupils in skill-based subjects. There is a growing need to investigate innovative instructional approaches such as collaborative learning, which has been shown in various contexts to improve student engagement and understanding. However, there is limited research on how collaborative learning specifically impacts academic outcomes in vocational subjects at the primary school level in Nigeria. This study, therefore, addresses the gap by examining the role of collaborative learning in enhancing pupils' academic performance in these subjects.

Objectives of the Study

The overall objective of this study to was explore the role of collaborative learning on pupils academic achievement in vocational subjects among pupils in primary schools in uvwie local government area of delta state, Nigeria. Specifically, the study sought to;

1. There is no difference between the pre-test and post-test academic achievement of pupils who learned vocational subjects using collaborative techniques and their counterpart who used conventional technique.
2. ascertain the difference between the experimental group who learnt vocational subjects using collaborative learning and control group who learnt using conventional method.

Research Questions

1. There is no difference between the pre-test and post-test academic achievement of pupils who learned vocational subjects using collaborative learning techniques and their counterpart who used conventional technique?
2. What is the difference between the academic achievement of pupils in experimental group and control group who were taught vocational subjects using collaborative and conventional methods

Null Hypotheses

1. There is no significant difference between the pre-test and post-test academic achievement of pupils who learned vocational subjects using collaborative techniques and their counterpart who used conventional technique.
2. There is no significant difference between the academic achievement of pupils in the experimental group and control group who were taught vocational subjects using collaborative and conventional method.

Research Methodology

A quasi-experimental research design was adopted for this study. The pre -test, post-test control group experimental design was used for the study. This design was adopted because it allows for the comparison of groups without random assignment while still assessing the causal effects of the treatment. The population of the study consisted of 8,932 pupils of the 21 primary schools in uviwe local government area of delta state, from this population, a sample size of 136 pupils were selected using purposive sampling. Purposive sampling was also used to select the two schools based on

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their similarity in academic performance, size, and accessibility. Within each school, intact classes were used to form the experimental and control groups to maintain natural classroom settings. Each is made up of sixty - eight (68) pupils were selected from each school. One school served as the experimental group, and the other served as the control group. The instrument for data collection for the study was agriculture science achievement Test. The items of this instrument were developed by the researchers from the agriculture science content in primary five. The instrument consisted of 10 Multiple-choice questions based on primary school curriculum content for agriculture science. The instrument was validated by experts in education and pilot tested to ensure reliability. The experimental group received the treatment. while the control group continued with conventional instruction. Pre-tests were administered to both experimental and control groups to determine their baseline knowledge. After the treatment on the experimental group, a post-test was conducted to measure the effect of the treatment. Data collected were analyzed using descriptive statistics (mean and standard deviation) and inferential statistics (e.g., t-test) to determine the significance of the difference between the two groups

Presentation of Results

Research Question 1: There is no difference between the pre-test and post-test academic achievement of pupils who learned vocational subjects using collaborative techniques and their counterpart who used conventional technique?

Table 1: Descriptive statistics of pupils' results pre-test and post-test academic achievement of pupils who learned vocational subjects using collaborative techniques and their counterpart who used conventional technique

Groups	N	Mean	DF	STD
Pre – test	68	30.26	25.90	7.601
Post – test	68	56.16		11.719

Based on table 1 above , shown the result of pre-test and post – test academic achievement of pupils who learned vocational subjects using collaborative technique and their counterpart who used conventional technique. The mean score of the pre – test is 30.26 . while the mean score of the post-test is 56.16. The mean differences between pre-test and post-test as 25.90. However, the post-test mean score is greater than the pre-test means scores. Therefore, the result indicated that collaborative learning technique has positive effect on students' academic achievement in vocational subjects in primary school in uvwie local government area in delta state.

Research Question 2: What is the differences between the academic achievement of pupils in experimental group and control group who were taught vocational subjects using collaborative and conventional methods?

Table 1: Descriptive statistics of pupils' results of the experimental and control groups on the learning of vocational subjects using collaborative learning and conventional method

Groups	N	Mean	DF	STD
Experimental Group	68	56.16	24.84	10.635
Control Group	68	31.32		09.989T

Based on the result in table2, shows that mean scores of for post-test of for experimental and control group. The experimental group learnt using collaborative learning technique has the highest mean score of 56.16. while pupils who learnt using conventional method has a mean score of 31.32. Hence, the differences exist between those learnt using collaborative learning technique and those learnt using conventional method is 24.84. Based on the result, collaborative learning technique has significant effect on pupils' academic performance in vocational subjects in primary school in uvwie local government area of delta state.

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Hypothesis 1: There is no significant difference between the pre-test and post-test academic performances score of pupils who learnt vocational subjects using collaborative learning techniques and those using conventional method.

Table 1: Analysis of paired sample on t- test for hypothesis one (pre-test and post -test)

Groups	N	Mean	DF	STD
Pre – test	68	30.26	25.90	7.601
Post – test	68	56.16		11.719

Based on the result in Table 3, shown the result tested with paired sample t-test. The hypothesis one which state that there is no significant difference between the pre-test and post-test academic performances score of pupils who learnt vocational subjects using collaborative learning techniques and those using conventional method in primary school in uvwie local government area of delta state was rejected. The researchers concluded the differences do exist between pre-test and post-test due p-value obtained is 0.000 ($p < 0.05$). Hence, collaborative learning technique in teaching pupils has positive effect on their academic performance in vocational subjects in primary schools in uvwie local government area of delta state.

Hypothesis 2: There is no significant differences between the experimental group of pupils who learnt vocational subjects using collaborative learning and control group who learnt using conventional method.

Table 1: Mean and Standard deviation of the respondents on experimental and control groups

Groups	N	Mean	DF	STD
Experimental Group	68	56.16	24.84	10.635
Control Group	84	31.32		09.989T

Based on the result in table 4, hypothesis 2 which state that there is no significant differences between the experimental group of pupils who learnt vocational subjects using collaborative learning and control group who learnt using conventional method in primary school in vuwie was rejected. It happened due to the p-value is 0.000 ($p<0.05$) therefore, using collaborative learning technique has positive effect on pupils academic performance in primary schools in uvwie local government area of delta state.

Discussion of findings

In discussing the hypothesis one, which states that there is no significant difference between the pre-test and post-test academic performances score of pupils who learnt vocational subjects using collaborative learning techniques and those using conventional method. This hypothesis was rejected . Therefore, the finding of this present study revealed that there is a significant difference between the pre-test and post-test academic performances score of pupils who learnt vocational subjects using collaborative learning techniques and those using conventional method. Hence, it means that pupils who learnt vocational subjects using collaborative learning technique perform better than their counterpart who use conventional method in primary schools in uvwie local government area of delta state. This present finding is in line Han and Ellis (2021) who opined that collaborative learning helpful to develop additional critical studying skills, such as critical thinking, decision-making, higher order metacognitive, and problem-solving, which lead to positive attitudes and motivation in learning, enhanced student engagement and deeper learning, and, ultimately, better academic performance. Similarly, Slavin (1996) conducted a meta-analysis of studies on cooperative learning and found that it had a positive effect on academic achievement across all subject areas. Furthermore, Zou (2020). Conducted a study on gamified flipped EFL classroom for primary education pupils and teacher perception. The study revealed that there is a significant impact on pupils' performance if compared to conventional method of teaching. The hypothesis two

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which predicted that there is no significant differences between the experimental group of pupils who learnt vocational subjects using collaborative learning and control group who learnt using conventional method. This hypothesis was not accepted. Therefore, the finding shown that there is a significant difference between the experimental group of pupils who learnt vocational subjects using collaborative learning and control group who learnt using conventional method. This is not line with the finding of Kulo (2021) who revealed that students who took part in collaborative learning method have the following advantage – increase student retention, builds self-esteem, enhances students' satisfaction with the learning experience, and promotes a positive attitude towards the subject matter.

Conclusion

Based on the findings, the researchers concluded that collaborative learning technique is better than conventional method in learning vocational subjects in primary school. It also concluded that pupils expose to experimental treatment using collaborative learning techniques perform better than their counterpart exposed to conventional method.

Recommendations

Based on the findings and conclusions of this study, the following recommendations were made:

1. Local education authority and heads of primary schools should trainprimary schools teachers on the use collaborative learning technique
2. Primary schools pupils should be exposed by teachers in the use of collaborative learning of vocational subjects in the classroom.

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Effects of Cloud - Computing Instruction on Interest and Performance in Genetics Concept among State Colleges of Education Biology Students in North-West, Nigeria

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Abstract

This study investigated the Effects of Cloud Computing Instruction on Interest and Performance in Genetics among Biology Students in States Colleges of Education, North-West Zone Nigeria. The study has Four (4) Research Objectives, Four (4) Research Questions, Four (4) Null Hypotheses tested at p≤0.05 level of significance using Quasi-experimental design. Four groups of students were used for data collection: the two experimental and control groups were pre-tested before treatment; Post-tested and post post-tested to determine the effect of the treatments on performance and interest among groups. The study has total population of 1,360 NCE III Biology students in Seven States Colleges of Education in North-West, Nigeria. From the figure, a total number of 200 NCE III Biology students were sampled. Two validated instruments with reliability coefficient of 0.74 and 0.83 namely; Genetics Performance Test (GPT) and Students Interest to Genetics Questionnaire (SIGQ) were used for data collection. Research questions were answered using mean, mean rank and Standard Deviations. Null Hypotheses were tested using ANCOVA, Independent t-test, Man Whitney (U-test), Kruskal Wallisat 0.05 level of significance. Findings show that, significant difference was obtained between the mean academic performance scores of experimental and control group in favour of experimental group. The mean Interest scores of experimental group is greater than that of control group, Based on the findings of the study, the researcher recommends that the State Ministries of Education should collaborate with professional bodies such as STAN to train teachers through workshops, and seminars on the use of Cloud Computing Instruction in teaching Biology at Colleges.

Keywords: Coud-Computing, Interest, Performance, Genetics, Biology Students

Introduction

Science is a dynamic and objective process of seeking knowledge, a way of explaining events and phenomena in nature. Science is also men, women and children investigating, inquiring and seeking verifiable knowledge of what the search leads to a new discovery. Science is classified into so many branches such as Chemistry, Physics, Biology and Basic Science. Biology however is the branch of science which studies life. It is a subject matter of great importance and concern to all. Biology helps to develop attitudes and science process skills such as observation, inferring, classifying, hypothesizing, questioning, measuring, interpreting, communicating, predicting, to mention a few. In view of the statements Okenyi (2012) states that, educating students in biology has been widely acknowledged as a way of promoting economic development, eliminating poverty and introducing social welfare. He further stated that, biology education is therefore the act of teaching and learning in order to inculcate or transfer the knowledge of Biology to students. In another dimension Nlewem (2012), defined Biology as the study of natural phenomena and environment which results from curiosity of man and also as a branch of science which plays a vital role in providing knowledge of relevant concepts, scientific skills, environment and natural phenomena. Biology is one of the natural science subjects taught in colleges of education in Nigeria, where Nigeria Certificate in Education (NCE) is obtained. This certificate (N.C.E.) is recognized as the minimum teaching qualification in Nigerian schools. Colleges of education are responsible for the teachers training and issue them with NCE Certificate after training.

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Magashi (2018) opined that, exposure to Biology education offers the NCE biology students a wide range of relevance to all aspects of life. Biology is among the subjects on the curriculum of Nigerian Colleges of Education under the supervision of the National Commission for Colleges of Education (NCCE). According to (NCCE 2012), the main philosophy behind the subject is to produce knowledgeable, highly motivated professional and effective teachers of Biology who will be able to develop in students, appreciation and understanding of biological process and principles. Despite this stated relevance of biology Okenyi (2016) find out that, there are shortages of qualified Biology teachers in Nigerian schools, and the so called teachers of the subject are not professionally qualified and may have the knowledge of the subject but lack the method. Okoli (2006) stated that, overwhelming majority of "science teachers prefer the conventional method of teaching and therefore shy away from innovative methods like conventional method. Also, Usman (2010) observed that, conventional method encourages rote learning without understanding, thereby resulting in poor performance among students. Rauschenberg (2015) added that, teaching and learning is now becoming easier, motivating and interactive due to new innovations in technology. In that respect, Tambaya, Lawal, and Ukor (2016) mentioned that, technology has recently provided qualitative teaching and learning materials to help both teachers and learners during teaching and learning sessions were for many years, educational materials have mostly been static texts with pictures printed on paper and in books with rapid developments in digital content and access to schools, these initiatives are geared towards development and provision of digital aids to schools all over the world. One of the aspects of Information and Communications Technology is the cloud computing, in which Abifarin (2016) stated that, the word cloud is used as a metaphor for the internet. So, the phrase cloud computing means "a type of internet-based computing" where different sharing of network are delivered to an organization's computer and devices through the internet. Rania (2017) observed that, cloud computing in teaching and learning of science is the use of it in institutions of higher learning where it has provided a number of benefits to universities and colleges. Cloud computing is cost effective thus efficient where the resources are minimal. Secondly, the academicians derive a positive experience from its use. Zubairu (2016) reported that, students perceived Biology as too wide and too difficult to comprehend, the Biology textbooks are too difficult to read and understand which has contributed to the fluctuating results of Biology in NECO and WAEC update. This is what informed the present study. The issue of interest is another area of concerned in science education in which Lazarides and Ittel (2012) asserted that, interest has a powerful influence on academic performance and they demonstrated the function of interest in fostering remembering and understanding materials and stimulating students' positively towards a topic. Abdullahi (2014) further added that, teaching NCE students using computer improves their interest, and helps them to have high potential academically and enhances their understanding of biology lessons. In addition, Chifwa (2015) stated that, Genetics is considered to be one of the most difficult topics to teach and learn in Biology by teachers and students in many part of the world its abstract and mathematics related nature. The Table 1.1 shows the result of NCE III Biology Students on Genetics.

Table 1: College of Education Genetic Results from 2015/2016 - 2021/2022 Academic Session of Sa'adatu Rimi College of Education Kano.

S/N	Academic Session	No of Registered students	No. of student Pass	No. of students Failed	Percentage of Pass %	Percentage of Failure %

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1	2015/2016	293	167	126	56.99	43'00
2	2016/2017	351	234	117	66.67	33.33
3	2017/2018	453	337	161	74.39	35.54
4	2018/2019	470	252	218	53.62	48.38
5	2019/2020	702	291	411	41.45	58.54
6	2020/2021	834	346	488	41.48	58.51
7	2021/2022	967	429	538	44.36	55.64

Source: Exam and Record office Sa'adatu Rimi College of Education Kano, April, 2022

It is against the background of the Table 1, that this study is centered.

Objectives of the Study

The study has the following objectives, To;

1. Determine the effects of cloud computing instruction on academic performance of state colleges of education Biology students taught genetics concept using cloud computing instruction;
2. assess the effects of cloud computing instruction on academic performance between male and female state colleges of education Biology students taught genetics concept using cloud computing instruction;
3. ascertain the interest levels of state colleges of education Biology students taught genetics concept using cloud computing instruction;
4. find out the interest levels between male and female state colleges of education Biology students taught genetics concept using cloud computing instruction;

Research Questions

The following research questions formulated are addressed in the study;

1. What is the mean difference of the academic performance scores between state colleges of education Biology students taught genetics concept using cloud computing instruction and those taught using conventional method?
2. What is the mean difference of the academic performance scores between male and female state colleges of education Biology students taught genetics concept using cloud computing instruction.
3. What are the interest levels of state colleges of education Biology students taught genetics concept using cloud computing instruction and those taught using conventional method?
4. What are the interest levels between male and female state colleges of education Biology students taught genetics concept using cloud computing instruction?

Null Hypotheses

The following null hypotheses were formulated and tested at $P \leq 0.05$ level of significance.

HO_1: There is no significant difference in the mean academic performance scores among state Colleges of education Biology students taught genetics concept using cloud computing instruction and those taught using conventional method.

HO_2: There is no significant difference in the mean academic performance scores between male and female state colleges of education Biology students taught genetics concept using cloud computing instruction.

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HO_3: There is no significant difference in the interest levels of state colleges of education Biology students taught genetics concept using cloud computing instruction and those taught using conventional method.

HO_4: There is no significant difference in the interest levels between male and female state colleges of education Biology students taught genetics concept using cloud computing instruction.

Research Methodology

The research design adopted for the study is a quasi-experimental control group design employing pretest, posttest and post posttests as recommended by (Kerlinger, 1973& Adamu, 2014). A pretest (0_1) was administered to both the experimental and control groups using same test instrument before treatment so as to determine whether there is no significant difference in the academic performance of sample selected before the treatment exposure. The treatment was conducted by teaching genetics concepts to the Experimental Groups (EG), using Cloud Computing Instruction (CCI), while the Control Group (CG) was taught the same concepts using conventional method for the period of six weeks. A post-test (0_2) was administered after six weeks of the treatment using the same test Instruments to determine the effectiveness or otherwise of the treatment on academic performance in genetics. The population for the study comprises all NCE III Biology students of the seven state colleges of education in north-west zone are 1,360 NCE III Biology students. Out of these numbers 547 are females while 813 are male the age range of the students is from 18 to 25 years of age. All Biology students in these colleges offer Genetics BIO 324.The summary of the population for the study is contained in Table 2.

Table 2: Population of the Study

S/N	College	Ownership	Male	Female	Total
1.	Adamu Augie COE Birnin Kebbi, Kebbi	State	103	68	171
2.	Isa Kaita COE Dutsin-ma, Katsina	State	119	71	190
3.	Jigawa State COE Gumel,	State	100	73	173
4.	Kaduna State COE Gidan Waya.	State	63	50	113
5.	Sa`adatu Rimi COE Kano.	State	256	165	421
6.	Shehu Shagari COE Sokoto.	State	90	64	154
7.	Zamfara State COE Maru.	State	82	56	138
	Total		813	547	1,360

Sources: NCCE (2021) and Examination Office Departments of Biology of the Colleges of Education North-West (2022)

The sample for the study consisted of two state colleges of education from the seven state colleges of education in the study area. To select these two colleges, sampling random sampling technique was used. Simple random sampling technique from the hart was used for selection of two colleges out of the seven State colleges of Education located in the study area. The two states owned colleges selected formed one experimental and one control groups. The selected colleges of education were found to be equivalent in terms of their performance because the colleges selected were given pretest and the result of pretest was subjected to Analysis of variance in which ANOVA result showed no

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significant difference among the colleges. Also, the colleges of education used in the study are co-educational. The second stage of the sampling involved the selection of students for the study using simple random sampling technique using balloting. The sample consisted of 200 NCE III Biology students drawn from the two colleges of education in the study area. That is, students from Jigawa State College of Education Gumel and Isa Kaita College of Education Dutsinma Katsina. To select the 200 subjects, the researcher used simple random sampling techniques in line with the central limit theorem, which proposed a minimum of 30 subjects as viable for experimental research (Tuckman, 1975 & Sambo, 2008). Where 95 subjects form the two experimental groups and also 105 subjects form the control groups. Table 3 shows the Sample for the Study.

Table 3: Sampled for the Study

S/N	Groups	Sample Selected Based on Gender		Total
		Male	Female	
1	Experimental College B (EG_2)	53	42	95
2	Control College D (CG_2)	56	49	105
	Total			200

Three instruments were used for the study, Genetics Performance Test (GPT), Students Interest to Genetics Questionnaire (SIGQ) and lesson Plans for both experimental and control groups. The Genetics Performance Test (GPT) was developed by the researcher based on the selected topics taught. The test is made up of two sections (A and B). Section A sought for the students‟ personal information like gender, names, age. Section B contained 40 multiple-choice (objective tests). The items in section B were evenly distributed over topics chosen for the study. The instrument and marking scheme for these 40 test items validated by experts. The lessons plans were used for both experimental and control groups respectively. The items for the GPT were designed according to Bloom's Taxonomy and the items were drawn from NCE III Biology syllabus (GPT) obtained from the Nigeria Certificate in Education Minimum Standard for Sciences 2012 Edition. The GPT was administered to both the experimental and control groups used as pretest, posttest and post-posttest. The purpose of the instrument was to assess the level of students‟ performance before and after treatment. Genetics falls within the NCE III course content and the course code is BIO 324 (NCCE 2012).

Presentation of Results

The summary of the result is hereby presented in Table 4a

Table 4a: Means and Standard Deviation of Pretest and Posttest Scores for Two Groups

Groups	Test	N	Mean	Std. Deviation	Mean Gain	Mean Difference
Exp	Pretest	53	14.30	5.16		
						-18.75
	Posttest	42	33.05	9.19		
					17.14	
Control	Pretest	56	14.70	4.14		
						-1.61
	Posttest	49	16.31	5.51		

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In Table 4a, the descriptive statistics, the mean performances showed that at the control group the pretest and posttest scores are 14.70 and 16.31 respectively with a mean gain of -1.61 while on the other hand at the experimental group the pretest and post test scores are14.30 and 33.05 respectively, with a mean gain of -18.75. This is an indication that, the teaching strategy improved the performance of the experimental group.

Hypothesis One: The data were analyzed as contained in the summary in Table 4b

Table 4b: ANCOVA Statistics for Experimental and Control Groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	R
Corrected Model	13126.95	3	3375.65	108.98	.00	Sig
Intercept	90620.01	1	90620.01	2273.8	.00	Sig
Groups	2501.66	1	2501.66	87.29	.06	NSig
Tests	4722.01	1	4722.01	142.38	.00	Sig
Groups * Tests	2903.26	1	2903.26	97.26	.00	Sig
Error	8011.03	236	41.22			
Total	11475	240				
Corrected Total	22637.98	239				

Significant at alpha 0.05 level

In Table 4b: the results indicates that the calculated P value in Groups versus tests value of 0.00 is lower than the 0.05 and its computed F value of 97.26 is above the F critical value of 3.000 at df1. Even between groups and between tests the p value of 0.00 is lower than the 0.05. Consequently, the null hypothesis is therefore rejected.

Research Question Two: The data from pretest and posttest scores was subjected to mean and standard deviation for both groups. The summary is presented in Table 5a.

Table 5a: Mean and Standard Deviation for Male and Female Experimental Group for State Colleges

Gender	N	Mean	SD	Mean difference
Male	53	33.76	6.84	
				1.43
Female	42	32.33	11.13	

In Table 4a, the computed mean performance scores are 33.76 and 32.33 by male, while the female state colleges of education taught genetics using cloud computing instruction are 32.33 and 11.13 respectively, implying an insignificant mean difference of 1.43 in favor of the male students. Cloud computing instruction is hereby retained. This is an indication that, the strategy is gender friendly.

Hypothesis Two: The data collected from posttest scores is presented in summary of Table 5b

Table 5b: Independent t-test Statistics for Male and Female of Experimental Group

Gender	N	Mean	SD	Mean difference	df	t calculate	t critical	P	Remarks
Male	53	33.76	6.84						
				1.43	58	0.60	1.96	0.55	NSig
Female	42	32.33	11.13						

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No Significant at alpha 0.05 level, t computed =0.93 < t critical value of 1.96 at degree of freedom 58. In Table 4.4b, the analysis indicates that the calculated value of 0.55 is greater than the 0.05 alpha level of significance. Consequently, the null hypothesis is hereby retained.

Research Question Three: The results from posttest scores of students interest to genetics questionnaire was subjected to mean rank and mean rank differences of both the male and female for the experimental groups. The summary of the findings is presented in Table 6a

Table 6a: Mean Rank Statistics for Experimental and Control Groups

Groups State	n	Mean Rank	Sum of Ranks	Mean Rank differences
Experimental	53	37.98	1139.50	
				14.96
Control	56	23.02	690.50	

In Table 4.9a, the Mean Rank Interest of the state students taught genetics concept using cloud computing instruction and those taught using conventional method are found to be 37.98 and 23.02 respectively. In the same vein, their sums of Ranks are 1139.50 and 690.50 respectively, which shows that, the state students taught genetics concept using Cloud Computing Instruction have a significant higher interest than their counterparts taught using conventional method.

Hypothesis Three: The data from the posttest scores were subjected to Mann Whitney. The summary of the findings is presented in Table 6b

Table 6b: Mann Whitney test (U-test) Difference in the Interest Levels for State Colleges for Experimental and Control Groups

Groups state	N	Mean Rank	Sum of Ranks	Mann-Whitney U	P	R
Experimental	56	23.02	1139.50			
				225.500	0.001	Sig
Control	56	23.02	690.50			

Significant at alpha 0.05 level

Table 4.9b of non-parametric test of Mann Whitney statistics, the P value of 0.001 is below the 0.05 alpha level of significance from this background of argument, it shows that, state students taught genetics concept using cloud computing instruction have significant higher interest than their counterparts taught using conventional method. Therefore, the null hypothesis is hereby rejected.

Research Question Four: The result of posttest score is presented in Table 7a

Table 7a: Mean Rank and Mean Rank Differences in Interest Levels of Male and Female or Experimental and Control Groups

Groupings States	n	Mean Rank	Mean Rank differences
Experimental Male	53	35.63	
			4.70
Experimental Female	42	40.33	
Control Male	56	20.13	
			5.77
Control Female	49	25.90	

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In Table 4.10a of the mean rank statistics, Their Mean Rank Interest of the state students are 20.13, 25.90, 35.63 and 40.33 by Control Male, Control Female, Experimental Male and Experimental female respectively. It shows that both male and female state college students taught genetics concept using cloud computing have higher interest than those taught using conventional method.

Hypothesis Four: The data from posttest scores were subjected to Kruskal Wallis. The summary of the findings is presented in Table 7b

Table 7b: Kruskal Wallis test on Difference in Interest Levels between Male and Female State Colleges for Experimental Groups

Groupings States	n	Mean Rank	df	H	P	R
Experimental Male	53	35.63				
Experimental Female	42	40.33				
			3	12.48	0.00	Sig
Control Male	56	20.13				
Control Female	49	25.90				

Significant at alpha 0.05 level

Based on the outcome of the non parametric test of Kruskal Wallis statistics of Table 7b, the P value of 0.00 is lower than the 0.05 alpha level of significance. From this background of discussion, it shows that, both male and female state colleges students taught genetics concept using cloud computing have higher interest level than those taught using conventional method. Therefore, the null hypothesis is hereby rejected.

Discussion of Findings

The finding of hypothesis one is not in line with that of Bala (2018) who conducted study on gender effect on performance and retention in basic science through computer assisted instruction among secondary school students in Kano metropolis showed that, there is no significant difference in the level of performance between male and female students taught basic science concepts using computer assisted instruction. The finding of the hypothesis three support the findings of Nwanne and Agommuoh (2017), who investigated the Effect of Computer Assisted Instruction (CAI) On Students' Interest and achievement in physics in Imo state, Nigeria. Their findings revealed that the students in the experimental group who were treated with computer assisted concept mapping achieved significantly better than those in the control group.

Recommendations

1. There is need to encourage teachers to learn ICT especially the use of cloud computing instruction through sponsorship to workshops both within and outside the campuses.
2. Interest Levels of male and female students is more enhanced when Cloud Computing Instruction is used in teaching Biology than conventional method. There is a need for NCCE and TETFUND to equip ICT centres with facilities that support the use of the strategy such as computers, internet connectivity, and smart phones, among others to bridge the gender disparity.
3. The cloud computing instruction is gender friendly. Therefore, it should be used for teaching of genetics concepts for both male and female in both federal and state-owned colleges of education.

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Assessment of Income Level and Educational Qualifications on Antenatal-Care-Utilization among Pregnant Women Attending Secondary Health Facilities in Maiduguri Metropolis, Borno State, Nigeria

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Abstract

The purpose of this study was conducted to examined income level and educational qualification as predictors of antenatal care (ANC) utilization among pregnant women attending Secondary Health Facilities in Maiduguri Metropolis, Borno State. Two objectives were raised and two hypotheses were tested using multiple regression analysis. A cross-sectional research design was adopted for the study. Data were collected with a ten-item self-developed questionnaire on a four-point Likert type scale with a Cronbach's alpha reliability index of 0.88. Four secondary healthcare facilities were purposively selected across Maiduguri Metropolis. Within these facilities, the population comprised 1,431 pregnant women, from which a sample of 306 was determined using the Research Advisors table (2006). Systematic random sampling was employed for questionnaire administration, and 291 completed questionnaires were successfully retrieved. Descriptive statistics of frequency counts and percentages was used to describe the demographic characteristics of the respondents while, Inferential statistics of multiple regression analysis was used, indicated that income level and educational qualifications were both statistically significant predictors of ANC utilization. It was recommended that health authorities in Maiduguri Metropolis to design educational programs to inform younger women about regular utilization of ANC, provide additional support to unmarried or separated women, develop age-specific ANC initiatives, encourage family and partner support for pregnant women, integrate demographic factors into health planning, and establish monitoring systems to track ANC attendance patterns to enhance access and utilization across all primary healthcare facilities.

Keywords: ANC, Income Level, Educational Qualifications, Pregnant Women, Maiduguri Metropolis.

Introduction

The influence of income levels on the utilization of antenatal care (ANC) among pregnant women attending Secondary Health Facilities has been a significant topic of discussion in previous studies. Income plays a critical role in the decision of women to utilize ANC services. Women with higher income levels have better access to healthcare services, including ANC, compared to women with lower income levels (Babalola & Fatusi, 2009). In low- and middle-income countries, financial barriers hinder access to ANC services, including consultation fees, laboratory tests, and transportation to and from healthcare facilities Agarwal, Kirk, Sripad, Bellows & Abuya, (2016). These costs can be significant for family with limited income and are often cited as a significant reason for low ANC utilization rates among women from lower income groups (Chama, Chiliba & Koch, 2015).

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Researchers have explored various strategies to address the financial barriers to access ANC services among women from lower income groups. One such strategy is providing conditional cash transfer programs that incentivize women to attend ANC clinics by providing financial support (Dzakpasu et al., 2014). In Ghana, for instance, introducing free delivery care and health insurance led to more women attending ANC clinics and improved health outcomes (Dzakpasu et al., 2014). Similarly, providing financial incentives, such as vouchers for ANC services, has been found to be an effective strategy to improve ANC utilization among poor women in several studies (Scott, Beckham, Gross, Pariyo, Rao & Cometto, 2014). However, it is essential to note that income levels may not be the only factor that influences ANC utilization rates among pregnant women from lower income groups. Quality of care, availability of health facilities, and transportation barriers may also contribute to low ANC utilization rates (Tiruneh et al., 2016). Therefore, a comprehensive approach is needed to improve ANC utilization among women from lower income groups. Income is an essential determinant of antenatal care (ANC) utilization among pregnant women attending Secondary Health Facilities. Several studies have shown that women with higher income levels are more likely to attend ANC clinics than those with lower income levels (Babalola & Fatusi, 2009). In Nigeria, for instance, Babalola and Fatusi (2009) found that women in the highest wealth quintile were three times more likely to access ANC services than those in the lowest income level. Financial barriers are the most common reasons for low ANC utilization among women in lower income groups (ChamaChiliba & Koch, 2015). The costs associated with accessing ANC services include consultation fees, laboratory tests, and transportation costs to and from healthcare facilities (Agarwal et al., 2016). These costs can be significant for households with limited income and financial resources, leading to reduced ANC utilization rates.

Educational qualification is another critical factor that affects the utilization of antenatal care services among pregnant women attending secondary health facilities. A woman's educational Qualification can determine her knowledge and awareness of the importance of antenatal care, as well as her ability to navigate the healthcare system to access these services. Several studies have investigated the influence of educational qualification on the utilization of antenatal care among pregnant women. Studies have shown that women with higher levels of education are more likely to influence utilization of antenatal care services than women with lower levels of education (Esena, SodziTettey, Dzomeku & Aikins, 2019). Education also exerts a significant influence on ANC utilisation. Educated partners are more likely to understand the importance of maternal health services and provide financial, emotional, and logistical support (Aboagye, Osborne, Anyasodor, Yikindi, Adnani & Ahinkorah 2025). For example, in Nigeria, Esena, et al. (2019) observed that women with highly educated husbands were more likely to attend ANC than those whose partners had no formal schooling. This underscores the relational dimension of education, whereby male involvement in maternal health improves outcomes. The reasons for this association are multifactorial and could be linked to socioeconomic factors, such as greater access to resources and improved social support for women with higher levels of education. Women with higher levels of education are more likely to have better knowledge and understanding of the importance of ANC, making them more aware of the importance of timely antenatal care services. Education can also improve a woman's decision making power regarding her health, enhancing her ability to access and utilize ANC services. On the other hand, women with lower levels of education may have a lower socioeconomic status, making it harder for them to access and utilize ANC services. They may also have limited knowledge and understanding of the importance of ANC, which may lead to reduced utilization rates. They may also face challenges related to cultural

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and social norms that devalue their education and undermine their ability to access healthcare services. Educational qualification is an important predictor of antenatal care (ANC) utilization among pregnant women. Studies have shown that women with higher educational qualification are more likely to utilize ANC services than women with lower educational qualifications. The educational qualification of a woman influences her knowledge, awareness, and understanding of the importance of ANC in promoting good maternal and child health outcomes. Women with higher education qualification have been found to attend ANC clinics more regularly and early in their pregnancy than women with lower educational qualifications. A study conducted in Nigeria revealed that women with tertiary education were more likely to attend ANC clinics in the first trimester of pregnancy than women with lower education levels (Ogu, Ogunjuyigbe, Adeyenum, Ijeremeni & Olorunfemi, 2020).

Objectives of the study

Objectives of this study were to examine:

1. Income level as predictor of utilization of antenatal care among pregnant women attending secondary health facilities in Maiduguri Metropolis, Borno State
2. Educational qualifications as predictor of utilization of antenatal care among pregnant women attending secondary health facilities in Maiduguri Metropolis, Borno State

Research Questions

1. To what extend does income level predict antennal care utilization among pregnant women attending secondary health facilities in Maiduguri Metropolis, Borno State?
2. To what extend does educational qualifications as predictor of utilization of antenatal care among pregnant women attending secondary health facilities in Maiduguri Metropolis, Borno State?

Null Hypothesis

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

H_{01}: Income level does not significantly predict antennal care utilization among pregnant women attending secondary health facilities in Maiduguri Metropolis, Borno State

H_{02}: Education qualifications does not significantly predict antennal care utilization among pregnant women attending secondary health facilities in Maiduguri Metropolis, Borno State

Research Methodology

A cross-sectional survey design was employed for this study, which is appropriate for examining relationships among variables at a single point in time (Cherry, 2019). The population for this study consisted of 1,431 pregnant women attending antenatal care service in secondary health care facilities in Maiduguri Metropolis (Hospital Management Board, 2026). Based on Research Advisors table (2006), a sample of three hundred and six 306 pregnant women were appropriate for the study. Four secondary healthcare facilities (State Specialist Hospital, Umaru Shehu Ultra-Modern Hospital, Muhammad Shuwa Hospital (Nursing Home), and Maryam Abatcha Maternal and Child Hospital) were purposively selected for the study. Within these facilities, participants were selected using systematic random sampling to ensure representativeness. Data were collected using a 10-item self-developed questionnaire, employing a four-point Likert-type scale: with a responses of Strongly Agree (4), Agree (3), Disagree (2), and Strongly Disagree (1). The instrument demonstrated good reliability, with a Cronbach's alpha of 0.88. Descriptive statistics of frequency counts and percentages was used to describe the demographic characteristics of the respondents while inferential statistics, specifically multiple regression analysis, was conducted to test the hypotheses at a 0.05 significance level.

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Table 1: Demographic Characteristics of the Respondents

Items	Responses	Respondents	Percentage (%)
1. Income Level	a. Less than 50,000/Month	161	55.3
	b. More than 50,000/Month	130	44.7
2. Educational Qualification	a. No formal education	66	22.7
	b. Primary Leaving Certificate	56	19.2
	c. SSCE	52	17.9
	d. NCE/ND	47	16.2
	e. B.Sc /HND	70	24.1

n = 291

Table 1 presents the demographic characteristics of the 291 respondents in terms of income level and educational qualifications. Income level: The monthly income categories show that 161 (55.3%) earned less than 50,000 Naira, while 130 (44.7%) earned more than 50,000 Naira. Income significantly has greater tendencies to predict the utilization of antenatal care among pregnant women attending secondary health facilities in Maiduguri Metropolis, so the monthly income variability will allow for a robust analysis. Educational Qualification: The result in the Table on educational qualification of the respondents shows, 66 (22.7%) of respondents had no formal education, 56 (19.2%) had obtained primary leaving certificate, 52 (17.9) had obtained senior secondary school certificate, 47 (16.2%) had obtained NCE/ND while 70 (24.1%) had obtained B.Sc/HND. This means that, majority of the respondents 70 (24.1%) had obtained B.Sc/HND. The attainment of higher educational levels by the respondents have a greater tendency to predicted the utilization of antenatal care among pregnant women attending secondary health facilities in Maiduguri Metropolis, so the variable distribution on educational qualification appears adequate to determine the predictive variables.

Table 2: Level of Antenatal Care Utilization

Utilization	Frequency	Percent
Low Utilization	214	73.5
High Utilization	77	26.5
Total	291	100.0

Key = 1 - 2.49 Low Utilization 2.5 - 4.0 High Utilization

Table 2 shows the level of antenatal care utilization among the 291 respondents. The majority of pregnant women, 214 (73.5%), were classified as having low utilization of ANC services, while only 77 (26.5%) demonstrated high utilization. This indicates that most respondents do not consistently use antenatal care services at the recommended level. The key shows that low utilization corresponds to scores between 1 and 2.49 on the measurement scale, while high utilization corresponds to scores between 2.5 and 4.0, reflecting the overall limited engagement of the study population with antenatal care in Maiduguri Metropolis.

Hypotheses

H_{01}: Income level does not significantly predict antennal care utilization among pregnant women attending secondary health facilities in Maiduguri Metropolis, Borno State

H_{02}: Education qualifications does not significantly predict antennal care utilization among pregnant women attending secondary health facilities in Maiduguri Metropolis, Borno State

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Table 3: Regression Analysis Model Summary

Statistics	Value
R	.530
R Square	.28
Adjusted R Square	.265
Std. Error of Estimate	.30197

The coefficient of determination (R^2 = .28) suggests that 28% of the variance in the dependent variable is explained by the combination of the predictors of income level and educational qualification. The adjusted R^2 (.265) accounts for the number of predictors relative to the sample size, slightly reducing the explained variance to 26.5%, indicating a modest predictive capacity of the independent variables. The Std. Error of Estimate of .30197 reflects the average deviation of .302 units from observed value.

Table 4: Regression Analysis ANOVA on Demographic Characteristics on Antenatal Care Utilization among Pregnant Women attending Secondary Health Facilities in Maiduguri Metropolis Borno State

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	10.094	6	1.682	18.450	.000
Residual	25.896	284	.091		
Total	35.990	290			

Table 4 indicates that the regression model is statistically significant, F= 18.450, p < 0.000, showing that income level and educational qualifications collectively explain a significant portion of variance in antenatal care utilization, though the explained variance remains moderate at 28%.

Table 5:

Summary of Multiple Linear Regression Analysis on income level and Educational Qualifications as a Predictor of Antenatal Care Utilization among Pregnant Women Attending Secondary Health Facilities in Maiduguri Metropolis Borno State

n = 291

Source	B	Std. Error	Beta	T	P-value
Constant	1.568	0.092		17.052	<.001
Income Level	0.004	0.036	0.006	0.121	0.004
Educational Qualification	0.029	0.012	0.125	2.390	0.018

The multiple regression analysis indicated that income level had a coefficient of 0.004, a Beta of 0.006, a T-value of 0.121, and a pvalue of 0.004. The positive coefficient suggests that as Income Level decreases, the dependent variable is expected to increase slightly; however, the P-value indicates that this effect is was statistically significant. For Educational Qualification, the coefficient was 0.029, the Beta was 0.125, the T-value was 2.390, and the P-value was 0.018. This suggests that higher educational qualification is associated with an increase in the dependent variable, and the relationship was statistically significant. Thus, based on the regression results, both null hypotheses (Ho_1 and Ho_2) were rejected. income level and educational qualifications significantly predicted antenatal care utilization among pregnant women attending secondary healthcare facilities in Maiduguri Metropolis, Borno State.

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Findings of the study

1. Monthly income was statistically significant predictor of antenatal care utilization among pregnant women attending secondary health facilities in Maiduguri Metropolis Borno State.
2. Educational Qualification was statistically significant predictor of ANC utilization Women with higher educational attainment were more likely to utilize ANC services than those with lower educational levels.

Discussion of Findings

The findings of this study on income level and educational qualifications as predictors of antenatal care utilization among pregnant women attending secondary health facilities in Maiduguri Metropolis, Borno State, Nigeria. The results of the study show that, income level was statistically significant predictor of antenatal care utilization among pregnant women attending these health care facilities. This finding is supported by several studies. The finding of this study collaborate with finding that, women with higher income levels have better access to healthcare services, including ANC, compared to women with lower income levels (Babalola & Fatusi, 2009; Yohannes, Tarekegn, & Paulos (2014).Although the study conducted by Agarwal, Kirk, Sripad, Bellows and Abuya (2016) on the discontinuation of antenatal care visits in low and middle income countries found that, financial barriers hinder access to ANC services, including consultation fees, laboratory tests, and transportation to and from healthcare facilities. These costs can be significant for family with limited income and are often cited as a significant reason for low ANC utilization rates among women from lower income groups (Chama Chiliba & Koch, 2015).

Similarly, researchers have explored various strategies to address the financial barriers to access ANC services among women from lower income groups. One such strategy is providing conditional cash transfer programs that incentivize women to attend ANC clinics by providing financial support Dzakpasu Soremekun, Manu Asbroek, Tawiah, Hurt, & Kirkwood (2014). Furthermore, the finding of the study also shows that, educational qualification was statistically significant predictor of ANC utilization women with higher educational attainment were more likely to utilize ANC services than those with lower educational levels. This finding is in line with many other studies which showed that, educational qualification was statistically significant predictor of antenatal care utilization among women. Esena, SodziTettey, Dzomeku and Aikins, (2019), have shown that, women with higher levels of education are more likely to influence utilization of antenatal care services than women with lower levels of education. Gebremeskel, Dibaba & Admassu, (2018). A study conducted in Ethiopia revealed that women with secondary or higher levels of education were more likely to attend four or more ANC appointments than those with primary or no education, (Gebremeskel et al., 2018). Similarly, study carried out in Ghana found out that women with higher levels of education were more likely to receive timely antenatal care than those with lower levels of education (Esena et al., 2019). However, women with higher levels of education are more likely to have better knowledge and understanding of the importance of ANC, making them more aware of the importance of timely antenatal care services. Education can also improve a woman's decision-making power regarding her health, enhancing her ability to access and utilize ANC services. On the other hand, women with lower levels of education attainment may have a lower socioeconomic status, making it harder for them to access and utilize ANC services. They may also have limited knowledge and understanding of the importance of ANC, which may lead to reduced utilization rates. Women living in society with low educational awareness faced challenges related to cultural and social norms that devalue their education and undermine their ability to access healthcare services.

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Conclusion

The study revealed that antenatal care utilization among pregnant women attending secondary health care facilities in Maiduguri Metropolis was generally low, with most respondents falling within the low utilization category. The findings showed that income level significantly predicted antenatal care utilization, as women with less than 50,000/Month income demonstrated low levels of antennal care service utilization. Educational qualification also significantly influenced utilization, women with high educational qualifications are more likely to utilize antenatal care services than women with low counterparts. The regression model was statistically significant and explained a moderate proportion of the variance in antenatal care utilization. Thus, the study concluded that income level and educational qualification were important socio demographic predictors of antenatal care utilization among pregnant women in the study area.

Recommendations

1. Health care providers should develop plan that are tailored to the specific needs and characteristics of different demographic groups, considering factors such as income level and family support to improve utilizations of antenatal care services.
2. Government should Encourage partners involvement in ANC services, providing education and support to promote ANC utilization among pregnant women
3. Health educators should transmit adequate information and knowledge on specific socio demographics and antenatal care utilization to the pregnant women, who are found in this study to have low utilization of ANC services, using suitable channels and settings.

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Evaluation of Availability, Adequacy, Accessibility, Utilization and Maintenance of Pedagogical Apparatus on Metalwork Technology Teaching among Schools in Katsina State, Nigeria

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Abstract

This study examined the condition and use of pedagogical apparatus for teaching and learning Metalwork Technology in selected government technical and secondary schools in Katsina State, Nigeria. The study focused on four related dimensions: the availability and adequacy of workshop apparatus; accessibility and utilization of available equipment; maintenance practices; and challenges affecting the provision and effective use of workshop resources. A descriptive survey design was adopted and complemented with direct workshop observation to strengthen the evidence obtained from respondents. The population comprised 310 respondents, consisting of 30 Metalwork Technology teachers and 280 students from six selected institutions. A sample of 195 respondents was used, comprising all 30 teachers and 165 students selected through proportionate random sampling. Data were collected using the Pedagogical Apparatus Questionnaire (PAQ) and a Pedagogical Apparatus Observation Checklist (PAOC). The instruments were subjected to expert validation, while internal consistency was established using Cronbach's alpha. Descriptive statistics, including mean, standard deviation, frequency and percentage, were used to analyze the data. The findings indicated low availability of most essential workshop equipment, inadequate quantities and outdated machines, restricted student access, low utilization, and weak maintenance practices. Inadequate funding was the most frequently reported challenge, followed by lack of modern equipment, poor maintenance culture and shortage of technical personnel. The study concludes that the quality of practical Metalwork Technology instruction in the selected schools is constrained by deficiencies in workshop resources and their management. The study recommends increased and sustained funding, provision of modern equipment, preventive maintenance systems, improved access arrangements, and continuing professional development for teachers and technical support staff.

Keywords: pedagogical apparatus; Metalwork Technology; workshop facilities; equipment utilization; maintenance; technical education; Katsina State.

Introduction

Background to the Study

Technical and vocational education and training (TVET) is expected to connect education with the practical demands of work, entrepreneurship and economic development. Contemporary TVET policy places increasing emphasis on relevant skills, quality learning environments and stronger links between training institutions and changing labour-market needs (UNESCO, 2022). This expectation is particularly important in Metalwork Technology because the subject is practical by nature and requires learners to work directly with tools, machines, materials and workshop procedures.

Metalwork Technology encompasses activities such as fitting, machining, welding, fabrication, drilling, cutting and other metal-processing operations. Learners cannot develop these competencies effectively through theoretical instruction alone. They need repeated opportunities to observe demonstrations, handle tools, operate machines, practice procedures and receive feedback. This practical orientation makes the availability, adequacy, accessibility, utilization and maintenance of workshop apparatus central to the quality of instruction. Recent Nigerian studies similarly report

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continuing concerns about workshop resources and equipment utilization in technical education (Lappi & Onuh, 2021; Adamu, 2024; Ya'u et al., 2025). The problem is not simply whether a machine or tool exists in a workshop. A facility may be physically present but unavailable to students, insufficient for the class size, obsolete, unsafe, poorly maintained or rarely used. Consequently, assessment of workshop provision should consider the entire chain from availability and adequacy through accessibility, actual instructional utilization and maintenance. This broader perspective is consistent with recent evidence from Kano State showing that workshop facilities and equipment were not being utilized effectively and that funding and teacher preparation for improvisation remained important concerns (Ya'u et al., 2025). Experiential learning provides a useful educational perspective for understanding why these resources matter. In practical learning, knowledge develops through meaningful experience, reflection, conceptual understanding and further experimentation. Morris (2020), in a systematic review of experiential learning, emphasizes the importance of contextually rich concrete experience, critical reflection and active experimentation. In Metalwork Technology, functional workshop apparatus therefore provides the setting in which practical experience can occur.

Statement of the Problem

The effectiveness of Metalwork Technology instruction depends heavily on the opportunity learners have to engage with appropriate workshop tools, machines and instructional materials. However, the manuscript evidence from the selected schools indicates that many essential apparatus are either unavailable, inadequate in quantity, difficult for students to access, underutilized or poorly maintained. The low ratings recorded for modern machines are particularly concerning because technical education is expected to prepare learners for contemporary work environments. The practical consequence is that students may spend considerable time learning procedures theoretically without obtaining sufficient opportunities to practice them. Where equipment is limited, students may have to share machines in ways that reduce individual practice time. Where machines are obsolete or faulty, teachers may avoid practical activities or rely heavily on demonstrations. Where maintenance is weak, the condition of equipment can deteriorate further. Similar concerns have been documented in Nigerian technical education settings, including Gombe, Kano and North-Eastern Nigeria (Lappi & Onuh, 2021; Adamu, 2024; Ya'u et al., 2025). The central problem addressed by this study is therefore the gap between the practical requirements of Metalwork Technology and the actual condition and use of pedagogical apparatus in selected schools in Katsina State. Empirical evidence is needed to show not only what equipment is available, but also whether it is adequate, accessible, utilized and maintained, and what institutional challenges limit its provision.

Purpose of the Study

The purpose of the study was to examine the condition and use of pedagogical apparatus for teaching and learning Metalwork Technology in selected government technical and secondary schools in Katsina State, Nigeria.

Objectives of the Study

1. determine the availability and adequacy of pedagogical apparatus used for teaching and learning Metalwork Technology;
2. examine the accessibility and utilization of available pedagogical apparatus by teachers and students;
3. assess the maintenance practices applied to Metalwork Technology workshop equipment; and

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4. identify the major challenges affecting the provision, management and effective use of pedagogical apparatus.

Research Questions

1. What is the level of availability and adequacy of pedagogical apparatus used for teaching and learning Metalwork Technology?
2. To what extent are available pedagogical apparatus accessible to and utilized by teachers and students?
3. What maintenance practices are applied to Metalwork Technology workshop equipment?
4. What major challenges affect the provision, management and effective use of pedagogical apparatus?

Significance of the Study

The study provides evidence that can assist education authorities, school administrators, Metalwork Technology teachers, curriculum planners and other stakeholders in making decisions about workshop provision. For government and funding agencies, the findings identify areas requiring investment. For school administrators, they highlight the importance of equipment-access arrangements and preventive maintenance. For teachers, the findings draw attention to the relationship between available resources and opportunities for practical learning. For students, better provision and management of workshop apparatus can increase opportunities for hands-on practice and competency development.

Scope of the Study

The study was limited to selected government technical and secondary schools offering Metalwork Technology in Katsina State. The institutions were Government Technical College Mashi, Government Technical College Ingawa, Government Technical College Funtua, Government College Funtua, Government College Katsina, and Government Secondary School Daura. The study focused on workshop tools, machines and other pedagogical apparatus, with particular attention to availability, adequacy, accessibility, utilization and maintenance.

Review of Related Literature

Technical and Vocational Education and Training

TVET is concerned with developing knowledge, skills and attitudes that enable individuals to participate effectively in work and economic life. UNESCO (2022) emphasizes that contemporary TVET should support employability, entrepreneurship, lifelong learning and transitions toward digital and sustainable economies. This broad mandate requires learning environments that are sufficiently resourced and responsive to occupational practice. For technical subjects, the workshop is not merely a physical room; it is an instructional environment in which learners translate concepts into practical performance. Consequently, the quality of workshop facilities can influence the opportunities available for practice and the extent to which teachers can implement practical components of the curriculum.

Metalwork Technology and Practical Skill Development

Metalwork Technology is inherently practice-oriented. Students are expected to develop competence in the safe and accurate use of hand tools, measuring instruments, machines and fabrication equipment. Such competence is developed progressively through demonstration, guided practice, repeated performance and feedback. Evidence from Nigerian studies continues to show that workshop facilities and equipment are important issues in the preparation of technical learners (Lappi & Onuh, 2021; Okwelle et al., 2022).

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Pedagogical Apparatus in Metalwork Technology

Pedagogical apparatus refers in this study to the tools, machines, equipment, instructional materials and related workshop resources used to support teaching and learning. Examples include lathes, welding machines, drilling machines, measuring instruments, cutting tools, workbenches and related safety resources. The usefulness of such apparatus depends on more than physical presence. It must be sufficient for the number of learners, functional, accessible, safe and aligned with curriculum requirements. Recent evidence from Kano State is especially relevant because it examined workshop facilities and equipment utilization specifically in Metalwork Technology and reported low utilization of facilities and instructional materials, alongside concerns about funding, maintenance and teacher improvisation (Ya'u et al., 2025).

Availability and Adequacy of Workshop Facilities

Availability refers to whether required equipment exists in the workshop, whereas adequacy concerns whether the available resources are sufficient in quantity, quality, functionality and suitability for the learners and curriculum. A workshop can therefore have some equipment and still be inadequate if a large class must share a small number of machines or if the machines no longer reflect current practice. Lappi and Onuh (2021) examined metalwork instructional facilities in Science and Technical Colleges in Gombe State and highlighted concerns relating to availability and utilization. Adamu (2024) similarly reported the importance of adequate workshop and training facilities in NCE (Technical) institutions in North-Eastern Nigeria. These studies support the need to examine workshop resources beyond a simple inventory of equipment.

Accessibility and Utilization of Equipment

Accessibility concerns the extent to which teachers and students can actually obtain and use available equipment during instruction. Utilization concerns the frequency and quality with which the equipment is employed for teaching and learning. These two dimensions are closely related but not identical. Equipment may be available but inaccessible because of restricted access, insufficient quantities, safety concerns, breakdowns or poor scheduling. Ya'u et al. (2025) found that workshop facilities and equipment in the Kano State study were not utilized effectively. Okwelle et al. (2022) also emphasized the importance of machine-operation skills for producing graduates who are ready for work. Together, these findings suggest that the presence of equipment must translate into actual learning opportunities if workshop resources are to contribute to competence development.

Maintenance of Workshop Equipment

Maintenance includes preventive servicing, inspection, cleaning, adjustment, repair and replacement of worn components. In Metalwork Technology, maintenance has an instructional as well as an operational function. Functional equipment supports regular practical activities, while neglected equipment can interrupt lessons and increase safety risks. The present study therefore treats maintenance as a core dimension of pedagogical apparatus rather than an administrative issue that is separate from teaching and learning.

Theoretical Framework: Experiential Learning Theory

The study is anchored in Experiential Learning Theory. The theory explains learning as a process in which learners develop knowledge through experience, reflection, conceptualization and active experimentation. Morris (2020) reviewed and refined Kolb's model, emphasizing contextually rich concrete experience, critical reflective observation, context-specific abstract conceptualization and pragmatic active experimentation. This perspective is directly relevant to Metalwork Technology because learners need opportunities to encounter real tools and machines, reflect on their performance, understand the principles involved and apply what they have learned in subsequent tasks. The theory also provides a rationale for examining availability, accessibility and utilization

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together. If essential apparatus are unavailable, learners have fewer concrete experiences. If equipment is available but inaccessible or underutilized, opportunities for active experimentation are reduced. Poor maintenance further interrupts the learning cycle because faulty equipment limits meaningful practical engagement. Thus, the condition and use of pedagogical apparatus can be understood as an important environmental support for experiential learning.

Empirical Review and Research Gap

Recent Nigerian evidence demonstrates that workshop-resource problems remain relevant across different technical education contexts. Lappi and Onuh (2021) investigated availability and utilization of metalwork instructional facilities in Gombe State. Okwelle et al. (2022) focused on operational skills required in metalwork and highlighted the need for continuing training to support work-ready graduates. Adamu (2024) assessed workshop adequacy and training facilities in NCE (Technical) institutions in North-Eastern Nigeria. Ya'u et al. (2025) examined workshop facilities and equipment utilization for Metalwork Technology in Kano State and reported low utilization. The present study extends this body of evidence by examining five closely connected conditions—availability, adequacy, accessibility, utilization and maintenance—within selected government technical and secondary schools in Katsina State. It also identifies the institutional challenges associated with these conditions. The combination of questionnaire evidence and direct observation provides a more rounded description of the workshop environment than an inventory alone.

Research Methodology

Research Design

A descriptive survey research design was adopted. The design was appropriate because the study sought to describe existing conditions in selected schools without manipulating the learning environment. Direct observation was also used to complement questionnaire responses and provide an additional source of evidence. The use of more than one source of evidence is consistent with established approaches to educational research and can strengthen interpretation of field conditions (Creswell & Creswell, 2021).

Area of the Study

The study was conducted in selected government technical and secondary schools in Katsina State, Nigeria. The institutions were Government Technical College Mashi, Government Technical College Ingawa, Government Technical College Funtua, Government College Funtua, Government College Katsina, and Government Secondary School Daura.

Population of the Study

The population consisted of 310 respondents: 30 Metalwork Technology teachers and 280 students involved in Metalwork Technology in the selected institutions.

Sample and Sampling Technique

A sample of 195 respondents was used. All 30 teachers were included through census sampling, while 165 students were selected through proportionate random sampling. This approach ensured that all available teachers in the selected schools were represented while the student sample was distributed proportionately.

Instruments for Data Collection

Two instruments were used: the Pedagogical Apparatus Questionnaire (PAQ) and the Pedagogical Apparatus Observation Checklist (PAOC). The questionnaire captured respondents' perceptions of availability, adequacy, accessibility, utilization, maintenance and challenges. The observation checklist was used to examine the physical condition and presence of workshop resources.

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Validity and Reliability

The instruments were subjected to expert review by specialists in Technology Education and Measurement and Evaluation. Internal consistency was established using Cronbach's alpha, with 0.70 treated as an acceptable minimum threshold for the instrument. Care was taken to ensure that questionnaire items were aligned with the research questions and the constructs being examined. Contemporary methodological literature emphasizes the importance of clear evidence for validity and reliability when reporting questionnaire-based research (Taber, 2020; Taherdoost, 2021).

Data Collection Procedure

Questionnaires were administered personally by the researcher, while workshop observations were conducted in the selected institutions. The use of direct observation was intended to complement respondents' perceptions and reduce reliance on a single data source.

Method of Data Analysis

Data were analyzed using frequency, percentage, mean and standard deviation. The analysis was organized around the four consolidated research questions. The original manuscript proposed independent-samples t-tests; however, the available compiled dataset does not contain respondent-level scores or sufficient group-level variance information to calculate valid t-values and p-values. Accordingly, no inferential statistics have been invented or reported in this publication-ready version. This is an important methodological safeguard because statistical significance cannot be established from mean differences alone.

Presentation of Results

Research Question 1: Availability and Adequacy of Pedagogical Apparatus

S/N	Pedagogical apparatus / adequacy indicator	Teachers' Mean	Students' Mean	SD	Remark
1	Lathes are available	2.10	1.95	0.78	Low
2	Welding machines are available	2.30	2.05	0.81	Low
3	Drilling machines are available	2.25	2.00	0.76	Low
4	Measuring instruments are available	2.40	2.20	0.70	Moderate
5	Cutting tools are available	2.15	1.90	0.82	Low
6	Equipment is sufficient in number	1.85	1.70	0.88	Very Low
7	Tools meet class-size needs	1.90	1.75	0.80	Low
8	Machines are modern	1.60	1.55	0.90	Very Low
9	Workshop space is adequate	2.20	2.10	0.75	Low

The results indicate that the availability and adequacy of workshop apparatus were generally low. Measuring instruments recorded the comparatively highest availability rating, while modernity of machines recorded the lowest ratings. The very low rating for equipment sufficiency also suggests that the number of available resources does not adequately match instructional needs. The pattern is consistent with recent Nigerian evidence reporting continuing concerns about workshop adequacy in technical education (Lappi & Onuh, 2021; Adamu, 2024).

Research Question 2: Accessibility and Utilization of Pedagogical Apparatus

S/N	Indicator	Teachers' Mean	Students' Mean	SD	Remark
1	Students have access to machines	2.00	1.85	0.79	Low
2	Teachers can freely use equipment	2.30	2.10	0.74	Moderate
3	Equipment is shared effectively	1.95	1.80	0.83	Low
4	Equipment is frequently used	2.10	1.90	0.80	Low
5	Practical lessons are regular	2.20	2.00	0.77	Moderate
6	Students actively use machines	1.95	1.80	0.85	Low

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Accessibility was generally limited, particularly from the students' perspective. Although teachers reported somewhat better access, students' access to machines and their active use of equipment remained low. The low rating for effective sharing also suggests that class size and equipment availability may restrict individual practice. The utilization pattern is comparable with recent findings from Kano State, where workshop facilities and equipment were reported to be underutilized for effective teaching and learning (Ya'u et al., 2025).

Research Question 3: Maintenance Practices

S/N	Maintenance indicator	Teachers' Mean	Students' Mean	SD	Remark
1	Equipment is regularly serviced	1.70	1.60	0.90	Very Low
2	Faulty machines are repaired quickly	1.80	1.65	0.88	Low
3	A maintenance culture exists	1.75	1.60	0.92	Very Low

Maintenance practices were rated very low overall. Regular servicing received the lowest ratings, while prompt repair of faulty machines was also weak. This pattern suggests that even where equipment is available, its instructional value may be reduced when preventive and corrective maintenance systems are inadequate. The finding reinforces the need to view maintenance as part of educational quality assurance rather than as an occasional response to equipment failure.

Research Question 4: Challenges Affecting Provision and Use of Pedagogical Apparatus

S/N	Challenge	Frequency	Percentage (%)
1	Inadequate funding	160	82
2	Lack of modern equipment	150	77
3	Poor maintenance culture	140	72
4	Shortage of technical staff	120	62

Inadequate funding was the most frequently identified challenge, followed by lack of modern equipment, poor maintenance culture and shortage of technical staff. The result indicates that the workshop problem is not caused by a single factor. Financial provision, equipment modernization, maintenance management and technical staffing appear to interact in shaping the quality of practical instruction. This interpretation is also consistent with recent evidence from Nigerian technical education settings (Adamu, 2024; Ya'u et al., 2025).

Discussion of Findings

Availability and Adequacy

The finding that most workshop apparatus were rated low in availability and adequacy indicates a substantial mismatch between the practical requirements of Metalwork Technology and the resources available to support those requirements. The particularly low rating for modern machines is important because technical education must remain responsive to changing occupational practices. UNESCO (2022) emphasizes that TVET systems should respond to evolving skills demands and support transitions in the world of work. The finding also agrees with Lappi and Onuh (2021), who reported concerns about the availability and utilization of metalwork instructional facilities in Gombe State. It is further supported by Adamu's (2024) assessment of workshop adequacy in NCE (Technical) institutions in North-Eastern Nigeria. Taken together, these studies suggest that workshop-resource constraints remain a recurring issue in Nigerian technical education.

Accessibility and Utilization

The low level of student access and utilization suggests that simply providing equipment is insufficient. Learners need regular, supervised opportunities to use the equipment themselves. From an experiential learning perspective, restricted access reduces the concrete experiences and active experimentation through which practical understanding develops (Morris, 2020). The result also

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supports the recent Kano State study by Ya'u et al. (2025), which reported inadequate utilization of workshop facilities and equipment. The implication is that schools should pay attention not only to procurement but also to equipment scheduling, class organization, teacher supervision and opportunities for individual practice.

Maintenance Practices

The very low maintenance ratings reveal a weakness that can progressively worsen other workshop problems. When machines are not serviced or repaired promptly, equipment becomes unavailable, and the effective stock of usable apparatus declines. Maintenance therefore affects availability, accessibility and utilization simultaneously. A preventive maintenance system would be more sustainable than relying mainly on repair after breakdown.

Challenges

The prominence of inadequate funding confirms that resource provision is closely linked to institutional capacity. However, funding alone may not solve the problem if procurement is not aligned with curriculum requirements or if equipment is not maintained after purchase. A more sustainable approach should combine adequate funding with needs assessment, equipment modernization, preventive maintenance, technical staffing and accountability mechanisms. This broader systems perspective is consistent with UNESCO's emphasis on transforming TVET to meet changing economic and skills demands (UNESCO, 2022).

Conclusion

The study concludes that pedagogical apparatus for teaching and learning Metalwork Technology in the selected schools in Katsina State are generally inadequate. Availability and adequacy were low, student access and utilization were limited, maintenance practices were weak, and inadequate funding was the most prominent challenge. These conditions may restrict the amount and quality of practical experience available to learners. Because Metalwork Technology is fundamentally practical, improving the workshop environment is essential to creating meaningful opportunities for skill development.

Recommendations

1. Government and relevant education authorities should increase and sustain funding for Metalwork Technology workshops, with priority given to equipment identified as essential by curriculum and class-size requirements.
2. Schools should introduce preventive maintenance schedules covering inspection, cleaning, servicing and timely repair of workshop equipment.
3. Modern and industry-relevant machines, tools, measuring instruments and safety equipment should gradually replace obsolete or non-functional resources.
4. School administrators should establish transparent equipment-access and workshop-use schedules that give students sufficient opportunities for supervised hands-on practice.
5. Metalwork Technology teachers and technical support personnel should receive continuing professional development on modern equipment, safe workshop practices, maintenance and appropriate improvisation.
6. Education authorities should periodically inspect and evaluate technical workshops using clear standards for availability, adequacy, functionality, accessibility, utilization and maintenance.

Contribution to Knowledge

The study contributes localized empirical evidence on the condition of pedagogical apparatus in selected government technical and secondary schools in Katsina State. Its main contribution is the consolidation of availability, adequacy, accessibility, utilization and maintenance into a single

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assessment framework, while also identifying the institutional challenges associated with workshop provision. The findings can serve as baseline evidence for future intervention studies, comparative studies across Nigerian states and research examining the relationship between workshop conditions and students' practical competencies.

Limitations of the Study

The study was limited to six selected government technical and secondary schools in Katsina State and therefore should not be generalized automatically to all technical and secondary schools in Nigeria. In addition, the compiled dataset available for this manuscript contains summary statistics rather than respondent-level scores. Consequently, inferential tests that require raw or complete group-level variance data have not been reported. Future studies should preserve respondent-level datasets so that inferential analysis and effect-size estimation can be conducted transparently.

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Effect of Revit Software on Students' Interest in Building Drawing among Colleges of Education in North-West, Nigeria

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Abstract

This study investigated the effect of Revit software on students' interest in Building Drawing in Colleges of Education in North-West Nigeria. The study was guided by two specific objective, two research questions and two null hypotheses. A quasi-experimental non-equivalent pretest-posttest design was adopted. The study was conducted in Colleges of Education in North – West Nigeria. The population comprised all 187 NCE III students offering Building Drawing in Colleges of Education in North-West Nigeria, The instruments used for data collection was Building Drawing interest questionnaire (BLDDRWIQ), The instruments were tested using test – retest methods and yielded correlation coefficient of 0.876. Data were collected through pretest and posttest, procedures. Mean and standard deviation were used to answer the research questions, while the independent samples t-test was employed to test the null hypotheses at the 0.05 level of significance. The findings revealed that students in both groups possessed comparable levels of interest in building drawing prior to the experiment Based on this finding the study concluded that Revit software is an effective instructional tool for enhancing students' interest in Building Drawing.

Keywords: Revit software, Building Drawing, student's, Interest, Building information modelling

Introduction

AutoCAD is a software application developed by Autodesk that enables Computer Aided Design and Drafting (CADD). The Software is used to produce 2D and 3D drawings. AutoCAD software allows users to conceptualize ideas, produce designs and drawings to the required levels of technical accuracy and even perform rapid design calculations and simulations across a wide range of industries. Computer aided design (CAD) involves the use of computers for creating designs and documents related to construction projects. It really comes into its own for large projects, where it allows for the bringing together of several models into one larger unit. CAD software was initially concerned with 2D CAD drawings of things such as floor plans, but in recent years software has evolved to keep up with the changes in the construction industry as a whole, and so it is more often used for 3D modelling these days – which allows for more accurate representations of buildings and

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facilities. The advantages of CAD include ease of use, helping you to spot errors and for automatic creation of documentation. However, the ease of use can mean that users get complacent and designs start to look similar, and it also means that users can forget about real-world issues. Building on the above, with the advancement of technology, digital tools such as Revit software have transformed the way building drawing is taught and learned. Revit is a Building Information Modelling (BIM) software that allows users to design, visualize, and simulate building structures in a three-dimensional environment. This interactive capability enhances students' understanding by providing realistic representations of building components. It is clear that researcher can truly predict the future of changing technologies, but researcher can speculate based on history. Computer aided drawing has come so far so quickly that nothing seems impossible, People are using computer to generates 4D models to represent plans and ideas. The power of personalized computers has created opportunities for growth in all industries and bridge the gap between resources Elom, (2021). Drawing will remain an in-demand services in many industries regardless of the advances in technology. The principles and techniques of drawing remain the same both manual and computer skills are necessary for any drafter that wants to be successful. Interest is one of the critical factor in learning. Students who are interested in a subject are more likely to participate actively, pay attention, and achieve better learning outcomes. However, the lack of engaging instructional tools can reduce students' interest in building drawing.

Statement of the Problem

Students' interest in Building Drawing is a problematic. Sustained interest drives attention, participation, motivation, and engagement; yet manual, non-interactive instruction provides limited exposure to contemporary digital design tools. The absence of technology-supported, interactive learning experiences can reduce students' enthusiasm and active participation in Building Drawing classes.

Objective of the Study

The Objective of this study was to determine the Effect of Revit software on Students' Interest in Building Drawing in Colleges of Education in North -West, Nigeria.

1. Find out the difference between pre-interest mean rating of Building drawing students in Experimental group and those in conventional group prior to the treatment.
2. Find out the difference between post interest mean rating of students taught Building drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North - West, Nigeria.

Research Questions

The following research questions were formulated to guide the study

1. What is the difference between the pre interest mean rating of Building drawing students in Experimental group and those in conventional group prior to the treatment
2. What is the difference between the post interest mean rating of students taught Building drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North - West Nigeria.

Null Hypotheses

The following null hypotheses were formulated for the study and tested at 0.05 level of significance.

H_{01}: There is no significant difference between the pre interest mean ratings of Building drawing students in Experimental group and those in conventional group prior to the treatment?

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H_{02}: There is no significant difference between post interest mean ratings of students taught Building drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North – West Nigeria.

Scope of the Study

This study focused on the effect of Revit software on students' interest in Building drawing in public Colleges of Education in North West Nigeria.

Literature Review

Revit software has emerged as one of the most widely utilized BIM applications in architecture, engineering, and construction education. Recent BIM education studies emphasized that Revit technology enables students to visualize building components in three-dimensional formats, detect design inconsistencies, simulate construction activities, and interact collaboratively within virtual modelling environments (Bui et al 2023, Oyesode et al 2023, Agirbas 2020, Turk et al 2022). Consequently, Revit-supported Building drawing instruction is increasingly regarded as a more effective and learner-centered instructional approach compared to conventional drafting methods.

Building on the above, Building drawing education is particularly important in Colleges of Education because it equips students with foundational technical competencies required for teaching and professional practice within Building Technology disciplines. According to the National Commission for Colleges of Education, (2023) Building Drawing constitutes a core aspect of Building Technology Education aimed at developing practical construction skills, technical communication abilities, and professional drafting competence among students. Recent educational technology research revealed that integrating digital modelling technologies into Building drawing instruction significantly improves students': academic achievement, spatial visualization abilities, practical understanding, psychomotor skills, creativity, and long-term retention (Petko 2025, ElSayary 2026, Oyesode et al., 2023, Bui et al 2023).Similarly, studies conducted within technical and vocational education environments established that students exposed to simulation-based and technology-supported instructional systems demonstrate stronger engagement, higher learning motivation, and better conceptual understanding than students taught using traditional lecture-based instructional methods (Gupta et al 2026, Turk et al 2022, Dwivedi et al 2023, Nikolopoulou et al 2021).

Research Methodology

Research Design

This study adopted a quasi-experimental research design, specifically the pretest-posttest non-equivalent control group design. The design was considered appropriate because the study involved intact classes where random assignment of participants into experimental and control groups was not practically feasible within the sampled Colleges of Education.

Area of the Study

The study was conducted in Colleges of Education offering Building Drawing in North-West Nigeria. The choice of the area is based on the availability of students offering Building Drawing.

Population of the Study

The population of the study comprised all NCE III Building Technology students offering Building Drawing in Colleges of Education in North-West Nigeria. These students are considered suitable because they have basic knowledge of Building Drawing and are directly involved in practical and theoretical learning subject.

Sample and Sampling Techniques

The sample for the study consisted of selected NCE III Building Technology students from sampled Colleges of Education in North-West Nigeria. Purposive selection of Colleges of Education offering

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Building Technology programmes was made. Intact class was used. Isa Kaita College of Education Dutsin Ma served as Experimental group and Federal College of Education Gidan Madi Sokoto served as Control group.

Instrument for Data Collection

The Building Drawing Interest Questionnaire was adapted by the researcher that developed by Amos et al, to determine students 'level of interest in Building Drawing.

Validation of the Instrument

The instruments used for this study was subjected to face and content validation to ensure its suitability and effectiveness in measuring what it was intended to measure.

Reliability of the Instrument

The interest questionnaire was tested using Cronbach Alpha reliability method.

Method of Data Collection

The data for the study was collected by the researchers with the help of research assistants that were selected and trained for the purpose of the study form the sampled Colleges of Education.

Method of Data Analysis

The data was coded and analyzed using Statistical Package for the Social Sciences (SPSS) version 27. Descriptive and inferential statistic were employed in the analyzing the data in line with the research questions and hypotheses of the study.

Presentation of Results

Research question One

What is the difference between the pre-interest mean rating of Building drawing students in Experimental group and those in Conventional group prior to the treatment?

A descriptive statistic was used to determine the difference in the pre-interest mean rating of Building drawing students in Experimental group and those in conventional group prior to treatment. The results in Table 1, revealed that there was a difference in mean rating of Experimental group (M = 2. 30, SD = 0.476) and conventional group (M = 2.23, SD = 0.316) at the pre-interest mean rating stage. This indicated that Experimental group and Conventional group possesses similar level of interest in Building drawing prior to the treatment.

Table 1: Descriptive statistics of pre-interest mean rating of students in Building drawing in Experimental group and those in Conventional group prior to the treatment?

Variable	Group	N	Mean	Std. Dev	MD
Pre-Test Interest Scores	Experimental	25	2.30	.476	
	Conventional	21	2.23	.316	
	Total	**46**			0.07

Note: N=Number of students, Std. Dev= Standard deviation. MD= Mean difference

Research Question two

What is the difference between the post interest mean rating of students taught Building drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North-West Nigeria.

A descriptive statistics was performed to find out the difference between post interests mean rating of students taught Building drawing using Revit software and those taught using conventional teaching method in colleges of education in North-West Nigeria. The results in Table 2, revealed that there was a difference in the post interest mean rating of students taught Building drawing using Revit software (M = 3.32, SD, 0.478) and those taught using conventional teaching method (M = 2.25, SD = 0.323). This indicated that Experimental group have better post interest mean rating than

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their counterpart in conventional group.

Table 2: Descriptive statistics of post interest mean rating of students taught Building drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North-West Nigeria

Variable	Group	N	Mean	Std. Dev	MD
Post-test Interest Scores	Experimental	25	3.32	.478	
	Conventional	21	2.25	.323	
	Total	46			1.07

Note: N=Number of students, Std. Dev= Standard deviation, MD=Mean difference

Hypotheses Testing

An independent samples t-test was used to test the null hypotheses

Test of Null Hypothesis 1

H_{01}: There is no significant difference between the pre-interest mean rating of Building drawing students in Experimental group and those in Conventional group prior to the treatment?

The statistical evidence of Independent samples t-test presented in Table 3. Indicated that there was no statistically significant different between the pre interest mean rating of Building drawing students in Experimental group (M = 2.30, SD = 0.476) and those in the conventional group (M = 2. 23, SD 0.316) t (44) = 0.603, P = 550. Null Hypothesis two was therefore accepted. This findings indicated that Experimental group and conventional group exhibited statistically equivalent levels of interest prior the treatment.

Table 3: Independent samples t-test of pre-interest mean rating of Building drawing students in Experimental group and those in Conventional group prior to the treatment?

Variable	Groups	N	Levene's Test for Equality of Variances F	Sig.	t-value	Mean	Std. Dev	p-value	Decision
Pre-test	Experimental	25	2.255	.140	.603	2.30	.47	.550	Accepted
	Conventional	21				2.23	.316		

Test of null hypothesis two

H_{02}: There is no significant difference between post interest mean rating of students taught Building drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North-West Nigeria.

The statistical evidence of Independent samples t – test in Table 4, Indicated that there was a statistically significant difference between the post interest mean rating of Experimental group (M = 3.32, SD = 0.478) and those in the conventional group (M = 2.25, SD = 0.323) t (44) = 8673, P = .004. Null Hypothesis Four was rejected. This finding indicated that students taught Building drawing with Revit software developed significantly higher levels of interest than those taught using conventional teaching method

Table 4: Independent samples t-test of posttest interest mean rating of students taught Building drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North-West Nigeria.

Variable	Groups	N	Levene's Test for Equality of Variances F	Sig.	t-value	Mean	Std. Dev	p-value	Decision

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Post-test Interest	Experimental	25	2.164	.148	2.573	3.32	.478	.004	Rejected
	Conventional	21				2.25	.323		

Finding of the Study.

1. The was no statistically significant difference between the pre interest mean ratings of students in the experimental and control groups prior the treatment. This indicates that the two groups had similar initial levels of interest in Building Drawing.
2. Students taught Building Drawing using Revit software recorded significantly higher post interest mean ratings than students taught using conventional teaching method

Discussion of the Findings

Pre Interest

The finding revealed that there was no statically significant difference between pre interest mean ratings of students in the two groups. The experimental group recorded a marginally higher mean interest mean ratings than the conventional group but the difference was not statistically significant. This suggests that the students began the study with comparable levels of interest in Building Drawing. The similarity in the students' initial interest level provides a fair basis for evaluating the effect of Revit-based instruction. Therefore the higher level of interest recorded by the by the experimental group after the treatment may reasonably be associated with the differences in their initial dispositions toward the subject.

Post interest mean rating

The fourth finding revealed a statistically significant difference between the post interest mean ratings of students in the experimental and conventional groups. Students exposed to Revit software obtained a higher mean interest mean rating than those taught using conventional teaching method. This indicates that Revit-based instruction enhanced students' motivation, engagement and enthusiasm for learning Building Drawing. The increased interest may be explained by the interactive nature of Revit software. Unlike instruction based mainly on manual demonstrations and static drawings, Revit allows students to participate actively in the design process. Students can explore virtual building models, modify components, observe the effects of their decisions, and repeat activities until they under standard the procedures. Such opportunities may make Building Drawing more engaging and meaningful.

Conclusion

The study concluded that Revit-based instruction significantly increased student's interest in Building Drawing. The interactive, visual and practical features of the software appear to create a more engaging learning environment and encourage students to participate actively in classroom active.

Recommendation

Based on the findings of this study, the following recommendations are proposed for consideration:

1. The Federal and State Governments should provide adequate Information and Communication Technology (ICT) facilities, including computer laboratories, multimedia projectors, stable electricity, and licensed Revit software to support effective instructional delivery.
2. The National Commission for Colleges of Education (NCCE) should review the Building Technology curriculum to incorporate Building Information Modelling (BIM) tools, particularly Revit software, as an essential component of Building Drawing instruction

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Effects of Integrating GeoGebra Software on Performance and Retention in Geometry among Secondary School Students in Zamfara State, Nigeria

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Abstract

This study investigated the upshot of integrating the GeoGebra software package on students' academic performance and knowledge retention in geometry across senior secondary schools in Zamfara State, Nigeria. Driven by persistent poor performance rates and heavy reliance on traditional rote methods, the study adopted a quasi-experimental post-test and post-post-test control group design. A sample of 415 senior secondary two (SS II) students was drawn from the population of 79,745 students across the state using an intact class approach. A convenience sampling approach was used in selecting Gusau Educational Zone for the study out of four zones, and a purposive sampling technique was employed in the selection of eight schools from four LGAs under study. Data was gathered using the researcher-developed "Geometry Performance and Retention Test" (GPART), validated by three experts and which attained a PPMC reliability coefficient of 0.82 after test-retest. Research questions were answered using descriptive statistics of mean and standard deviation, while independent samples t-tests analyzed the null hypotheses at a 0.05 level of significance. The findings revealed a statistically significant performance difference favoring students taught geometry using GeoGebra over conventional instruction (t=6.891, p=.000), leading to the rejection of null hypothesis one. Furthermore, gender did not exert a statistically significant influence on immediate academic performance under GeoGebra-mediated instruction (t=.548, p=.585), resulting in the retention of null hypothesis two and demonstrating equitable learning benefits. However, a significant gender difference emerged in long-term knowledge retention (t=2.386, p=.019), where female students achieved higher mean retention scores, leading to the rejection of null hypothesis three. The study concludes that interactive digital tools substantially improve academic achievement and cognitive recall. It recommends institutionalizing GeoGebra in the curriculum and supporting gender-inclusive pedagogies.

Keywords: GeoGebra software, Academic performance, Knowledge retention, Geometry

Introduction

Within Nigeria's educational framework, mathematics functions as a core academic pillar that builds essential problem-solving abilities, structural reasoning, and quantitative literacy for a data-driven society (National Council of Teachers of Mathematics [NCTM], 2024). Beyond standard arithmetic, the discipline acts as a universal catalyst for economic viability and technological advancement (OECD, 2023), allowing learners to critically analyze real-world situations and make informed decisions (Hanushek & Woessmann, 2020). Nevertheless, delivering effective math instruction faces major hurdles, particularly in abstract domains like geometry. Instructors in senior secondary institutions throughout Zamfara State encounter severe resource constraints such as a lack of visual aids, physical models, and interactive software that hamper effective teaching (Bello, 2025). To overcome these structural limitations, incorporating digital application tools has become a vital pedagogical shift. Research indicates that dynamic technologies greatly enhance student motivation,

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concept retention, and spatial visualization (Achor et al., 2023). GeoGebra stands out among these platforms by merging algebra, calculus, and geometry into a unified interactive space where students can actively explore and modify geometric shapes (Hohenwarter, 2024). Recent findings show that utilizing such digital applications successfully connects theoretical research with classroom practice, boosting active student participation (Ardina et al., 2025). Furthermore, historical analyses spanning two decades confirm that GeoGebra excels as an interactive medium that improves problem-solving, modelling, and knowledge retention over traditional methods (Awaji et al., 2025). This educational framework relies heavily on core variables: geometry, academic performance, and knowledge retention. Geometry provides the structural foundation for analyzing lines, points, shapes, and spatial dimensions. Academic performance reflects measurable achievement through testing, whereas knowledge retention denotes the long-term cognitive ability to recall and apply these mathematical concepts rather than relying on short-term memorization. Historically, geometry instruction relied on static illustrations and rote learning, which severely limited students' spatial abilities and overall performance in Zamfara State classrooms. Long-term geometric retention heavily predicts overall success in major external examinations like WAEC and NECO across Nigerian secondary schools (Njoku, 2024). Because geometry requires strong visual imagination, temporary memorization falls short, making interactive platforms like GeoGebra essential for visualizing structural characteristics (Tan et al., 2023). Additionally, gender dynamics in northern Nigerian mathematics education remain a critical discussion point. While past assumptions favored male spatial reasoning, recent studies demonstrate that technology-based instruction minimizes these performance gaps (Sanderson & Ojimba, 2024), empowering both male and female learners equally (Awodun & Oyeiyi, 2023).

Geometry functions as a foundational mathematical branch concerned with spatial relationships, measurements, and the properties of both two-dimensional plane figures and three-dimensional solid structures (Britannica, 2024; Clements & Battista, 2023). Tracing its origins back to ancient Egypt and Mesopotamia for land surveying and construction, the field evolved through Greek contributions into an abstract discipline encompassing Euclidean, analytic, and projective geometries (Chukwu, 2019; Britannica, 2024). Within secondary education, teaching geometry presents unique pedagogical challenges due to its abstract nature, making the development of spatial intuition and critical thinking essential (Kivkovich & Chis, 2016; Brown, 2021). To overcome traditional instructional barriers and rote memorization, educators increasingly rely on interactive computer software applications like GeoGebra an open-source dynamic platform integrating geometry, algebra, and calculus to provide real-time visual representations, stimulate problem-solving, and cultivate active student engagement (Hohenwarter, 2001; Akcay et al., 2023). Enhancing academic success in this domain is closely tied to knowledge retention, defined as the cognitive ability to store, recall, and apply fundamental geometric concepts over extended periods rather than relying on temporary memorization (Parker, 2023; Lutz & Huitt, 2018). Student performance and long-term retention are heavily influenced by pedagogical strategies, instructional materials, and learning environments, with traditional lecture methods frequently yielding low retention rates compared to interactive, technology-driven approaches (Tosun, 2015; Jelatu et al., 2018). Furthermore, demographic variables such as gender continue to be widely examined to determine whether performance and retention disparities exist between male and female learners when utilizing digital tools like GeoGebra in secondary classrooms (Sanderson et al., 2022). Recent empirical research extensively documents the profound pedagogical value of integrating GeoGebra software into secondary school mathematics to overcome the inherent abstractions of geometry. Studies

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employing quasi-experimental and mixed-methods designs consistently demonstrate that GeoGebra transforms passive classrooms into interactive environments, significantly improving student achievement, spatial visualization, and long-term knowledge retention compared to conventional lecture-based methods (Awaji et al., 2025; Awaji, 2021; Hidayat et al., 2023; Ekwue et al., 2023; Akwensi et al., 2023). Researchers emphasize that the dynamic manipulation of algebraic and geometric representations bridges the gap between theoretical concepts and practical understanding across diverse geographic regions, including Nigeria, Ghana, South Africa, and Malaysia (Ado & James, 2021; Ihechukwu & Chidi, 2020; Manganyana et al., 2020; Abari et al., 2019). Furthermore, evaluations of demographic variables within these technology-mediated settings frequently report that GeoGebra fosters equitable learning outcomes by narrowing historical gender disparities in spatial reasoning and performance (Ado & James, 2021; Ihechukwu & Chidi, 2020; Abari et al., 2019). Ultimately, the literature strongly advocates for institutional curriculum reforms and sustained teacher professional development to maximize the efficacy of dynamic software tools in modern mathematics classrooms.

Extensive empirical research demonstrates that integrating the GeoGebra application package into mathematics classrooms significantly enhances students' academic performance and conceptual understanding in geometry compared to traditional paper-pencil methods (Aliyu, 2019; Gamage & Charles-Ogan, 2019; Udofia & Uko, 2018). Studies across various regions including Nigeria, South Africa, Ghana, Malaysia, and Thailand consistently reveal that dynamic software environments improve visualization, foster active student engagement, mitigate the abstract difficulties of two- and three-dimensional shapes, and bridge the gap between theoretical instruction and practical application (Gadese, 2016; Ansah, 2020; Khansila et al., 2022; Adelabu et al., 2019; Tay & Mensah-Wonkyi, 2018; Chimuka, 2017; Onaifoh & Ekwueme, 2017; Seloraji & Eu, 2017; Ajaegba & Ekwueme, 2023; Shadaan & Eu, 2023; Dokochi et al., 2023). Furthermore, while technological integration generally boosts student interest and overall outcomes (Bright et al., 2024; Attahiru et al., 2025), investigations into gender disparities indicate that GeoGebra-mediated instruction helps democratize learning by yielding comparable or favourable performance and retention across both male and female students (Gamage & Charles-Ogan, 2019; Adelabu et al., 2019; Onaifoh & Ekwueme, 2017; Egbunu et al., 2017; Gumel & Galadima, 2014; Hamisu, 2017). Despite regional educational investments, students in Zamfara State continue to exhibit poor academic results in internal and external mathematics assessments, largely driven by traditional instructional approaches. Statistical records from the Ministry of Education and the National Bureau of Statistics reveal that between 2016 and 2025, WASSCE candidates in the state averaged a mere 20.03% credit pass rate in mathematics, alongside a 79.97% failure rate. Examiner reports consistently highlight widespread student deficiencies in solving both 2D plane geometry and 3D solid geometry problems. Driven by these persistent performance challenges, this study investigates the integration of GeoGebra software to shift classrooms toward active, student-focused discovery, reduce learning anxiety, and improve long-term geometric retention.

Objectives of the Study

1. Examine the difference in the performance of students taught geometry using GeoGebra package and those taught using conventional method in Senior Secondary Schools in Zamfara State.
2. Examine the influence of gender on the performance of students when GeoGebra software is utilized in the Geometry classroom in secondary schools in Zamfara State.

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3. Examine the influence of gender on the retention rate of students when GeoGebra software is utilized in the Geometry classroom in secondary schools in Zamfara State.

Research Questions

1. Is there any difference in the performance of students taught geometry using GeoGebra package and those taught using conventional method in Senior Secondary Schools in Zamfara State?
2. What is the influence of gender on the mean performance scores of secondary school students when GeoGebra software is utilized in the Geometry classroom in Zamfara State?
3. What is the influence of gender on the retention rate of secondary school students when GeoGebra software is utilized in the Geometry classroom in Zamfara State?

Null Hypotheses

H_{O1}: There is no significance difference between the performance of students taught geometry using GeoGebra package and those taught using conventional method in Senior Secondary Schools in Zamfara State.

H_{O2}: Gender does not exert any significant influence on the mean performance scores of secondary school students when GeoGebra software is utilized in the Geometry classroom in Zamfara State.

H_{O3}: Gender does not exert any significant influence on the retention rate of secondary school students when GeoGebra software is utilized in the Geometry classroom in Zamfara State.

Research Methodology

The study adopted a quasi-experimental design utilizing post-test and post-post-test experimental and control group arrangements to investigate causal impacts without random assignment. The target population comprised 79,745 Senior Secondary Two (SS2) students across 167 public senior secondary schools in Zamfara State, Nigeria. Due to regional security concerns, convenience sampling was utilized to select the Gusau Educational Zone, followed by purposive sampling to choose eight computer-equipped schools with balanced gender representation. An intact class sampling method yielded a total sample size of 415 students, divided into experimental and control groups. Data was collected using the researcher-developed "Geometry Performance and Retention Test (GPART)," a 50-item multiple-choice instrument validated by four subject-matter experts and proven reliable via a test-retest method yielding a Pearson Product-Moment Correlation coefficient of 0.82. Following a six-week treatment period utilizing the GeoGebra package alongside conventional instruction, a post-test was administered to measure academic performance, followed by a post-post-test three weeks later to assess knowledge retention. Data analysis was conducted using descriptive statistics (mean and standard deviation) for research questions, while t-test statistics executed via SPSS version 25.0 were employed to test all null hypotheses at a 0.05 level of significance.

Method of data analysis

The descriptive statistics of mean and standard deviation were used in answering all the research questions and the null hypotheses were analysed using the independent samples t-test statistics at .05 levels of significance.

Presentation of Results

Research Question One: Is there any difference in the performance of students taught geometry using GeoGebra package and those taught using conventional method in Senior Secondary Schools in Zamfara State?

Table 1: Summary of the descriptive analysis of the difference in performance of students' taught geometry using GeoGebra Software and those taught using Conventional Method

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Variables	N	$\bar{x}$	SD	S.E. Mean	Mean Diff.
Performance of Students in EG (GeoGebra)	108	39.83	5.458	.525	7.636
Performance of Students in CG (Conventional Method)	198	32.20	10.781	.766	

Source: Field Work, (2026)

Based on the descriptive analysis addressing Research Question One, there is a notable difference in the academic performance of senior secondary school students in Zamfara State taught geometry using the GeoGebra package compared to those taught using the conventional method. Specifically, the Experimental Group (GeoGebra) comprising 108 students recorded a higher mean performance score of 39.83 with a standard deviation (SD) of 5.458, whereas the Control Group (Conventional Method) with 198 students obtained a mean score of 32.20 with an SD of 10.781. The resulting mean difference of 7.636 in favour of the GeoGebra group indicates that students taught geometry using the GeoGebra software achieved superior performance and more consistent score distribution than their peers taught through the conventional method.

Null Hypothesis 1 (H_{01}): There is no significance difference between the performance of students taught geometry using GeoGebra package and those taught using conventional method

Table 2: Summary of the t-test analysis of the significance difference between the performance of students taught geometry using GeoGebra package and those taught using conventional method.

Variables	N	$\bar{X}$	SD	df	t-Crit	p-Value	Decision
Performance of Students in EG (GeoGebra)	108	39.83	5.458	304	6.891	.000	Rejected
Performance of Students in CG (Conventional Method)	198	32.20	10.781				

Source: Field Work, (2026) $\alpha \leq 0.05$ level of significance

The results in Table 2 evaluating Null Hypothesis 1 (H_{01}) indicate a statistically significant difference in the academic performance of students taught geometry using the GeoGebra experimental group (N = 108, Mean = 39.83, SD = 5.458) compared to those taught using the conventional control method (N = 198, Mean = 32.20, SD = 10.781). With a degrees of freedom (df) of 304, the resulting t-value of 6.891 and a corresponding p-value of .000 which is well below the standard .05 level of significance led to the decision that the null hypothesis is Rejected. This empirical evidence confirms that integrating the GeoGebra package significantly enhances students' geometry performance compared to conventional instructional methods.

Research Question 2: What is the influence of gender on the mean performance scores of secondary school students when GeoGebra software is utilized in the Geometry Classroom in Zamfara State?

Table 3: Summary of Descriptive Statistics of the mean performance scores of Male and Female Students taught geometry using GeoGebra Application Software.

Variables	N	$\bar{X}$	SD	S.E. Mean	Mean Diff.
Male performance	44	40.18	3.787	.571	.588
Female Performance	64	39.59	6.376	.797	

Source: Field Work, (2026)

Table 3 presents the descriptive statistics comparing the geometry performance scores of male (N = 44) and female (N = 64) students taught using the GeoGebra application software in experimental

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group. The analysis reveals that male students obtained a slightly higher mean performance score of 40.18 (standard deviation = 3.787), compared to a mean score of 39.59 (standard deviation = 6.376) recorded by their female counterparts. This yields a minor mean difference of 0.588 in favor of the male students, suggesting that while both genders benefited closely from the technology-enhanced instruction, male students achieved a marginally higher average score with less variability in their performance distribution.

Null Hypothesis 2 (H_{02}): Gender does not exert any significant influence on the mean performance scores of secondary school students when GeoGebra software is utilized in the geometry classroom in Zamfara State.

Table 4: Summary of the t-test analysis of the significance difference between performance scores of Male and Female Students taught geometry using GeoGebra Application Software.

Variables	N	$\bar{X}$	SD	df	t-Crit	P-Value	Decision
Male Performance	44	40.18	3.787	106	.548	.585	Retained
Female Performance	64	39.59	6.376				

Source: Field Work, (2026) $\alpha \leq 0.05$ level of significance

The t-test analysis presented in Table 4 examines the difference in performance scores between male (N = 44, $\bar{x}$ = 40.18, SD = 3.787) and female (N = 64, $\bar{x}$ = 39.59, SD = 6.376) students taught geometry using the GeoGebra application software. With a degree of freedom (Df) of 106, the analysis yielded a p-value of .585 against a critical t-value threshold. Since the p-value of .585 is greater than the .05 level of significance, the null hypothesis is retained, indicating that there is no statistically significant difference in academic performance between male and female students when using GeoGebra.

Research Question 3: What is the influence of gender on the retention rate of secondary school students when GeoGebra software is utilized in the geometry classroom in Zamfara State.

Table 5: Summary of descriptive statistics on the influence of gender on the retention rate of secondary school students when GeoGebra Software is utilized in the geometry classroom

Variables	N	$\bar{X}$	SD	S.E. Mean	Mean Diff
Male Retention Rate	44	36.50	4.100	.618	2.250
Female Retention Rate	64	38.75	5.246	.656	

Source: Field Work (2026)

Table 5 presents the descriptive statistics examining the influence of gender on the retention rate of secondary school students when GeoGebra software is utilized in the geometry classroom. The results show that the male students in the experimental group (N = 44) recorded a mean retention score of 36.50 with a standard deviation of 4.100, while their female counterparts (N = 64) obtained a slightly higher mean retention score of 38.75 with a standard deviation of 5.246. The resulting mean difference of 2.250 indicates that female students achieved marginally better retention rates than male students when exposed to GeoGebra-assisted geometry instruction, suggesting a positive performance trend among female learners in this technology-integrated learning environment.

Null Hypothesis 3 (H_{03}): Gender does not exert any significant influence on the retention rate of secondary school students when GeoGebra software is utilized in the Geometry classroom in Zamfara State.

Table 6: Summary of the t-test analysis of the significance difference in the geometry retention of male and female students when taught using GeoGebra Software.

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Variables	N	$\bar{X}$	SD	df	t-Crit	P-Value	Decision
Male Retention Rate	44	36.50	4.100	106	2.386	.019	Rejected
Female Retention Rate (GeoGebra)	64	38.75	5.246				

Source: Field Work, (2026) $\alpha \leq 0.05$ level of significance

Based on the independent samples t-test analysis presented in Table 6, the geometry retention of male and female students taught using GeoGebra Software was evaluated with a total degree of freedom (Df) of 106 at a 0.05 level of significance. The male students (N = 44) obtained a mean retention score of 36.50 with a standard deviation (SD) of 4.100, while the female students (N = 64) obtained a mean retention score of 38.75 with a standard deviation of 5.246. With a critical t-value (t-Crit) of 2.386 and a resulting p-value of .019, the p-value is less than the .05 alpha level, leading to the decision that the null hypothesis is rejected. This indicates that there is a statistically significant difference in the retention rates between male and female students taught plane geometry using the GeoGebra application package.

Summary of the Findings

1. The first finding revealed that sstudents' taught geometry using the GeoGebra package achieved a significantly higher mean performance score compared to those taught using the conventional instructional method. The independent samples t-test results, led to the rejection of Null Hypothesis 1. This confirms that integrating GeoGebra substantially enhances students' geometry performance.
2. The second findings of the study revealed that gender does not exert a statistically significant influence on the academic performance of students when GeoGebra software is utilized. Although male students recorded a marginally higher mean score than female students, Null Hypothesis 2 was retained, indicating that technology-enhanced geometry instruction benefits both genders equitably.
3. The third research finding revealed that there is a statistically significant difference in the retention rates of male and female students when taught plane geometry using GeoGebra. Female students recorded a higher mean retention score compared to male students, leading to the rejection of Null Hypothesis 3 and demonstrating a favorable retention advantage among female students in this digital environment.

Discussion of Findings

The first finding revealed that students taught geometry using the GeoGebra package achieved a significantly higher mean performance score compared to those taught using the conventional instructional method, leading to the rejection of Null Hypothesis 1. This outcome strongly aligns with contemporary and historical literature indicating that dynamic digital tools bridge the gap between theory and practice by replacing static illustrations and rote memorization with interactive exploration (Awaji et al., 2025; Aliyu, 2019). Furthermore, this supports the assertions of Achor et al. (2023) and Hohenwarter (2024), who emphasized that GeoGebra's integration of algebra and geometry enhances spatial visualization and student motivation, corroborating broader regional findings that technology-driven instruction consistently outperforms traditional lecture methods in secondary school mathematics (Gamage & Charles-Ogan, 2019; Akwensi et al., 2023). The second finding of the study revealed that gender does not exert a statistically significant influence on the academic performance of students when GeoGebra software is utilized, resulting in the retention of Null Hypothesis 2. While male students recorded a marginally higher mean score, the lack of statistical significance indicates that technology-enhanced geometry instruction benefits both

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genders equitably. This finding agrees with recent literature by Sanderson and Ojimba (2024) and Awodun and Oyeiyi (2023), which highlights that interactive digital platforms help dismantle historical gender disparities in spatial reasoning and mathematics achievement. By providing equal opportunities for visual manipulation and active engagement, GeoGebra fosters an inclusive learning environment where male and female learners perform on par, aligning closely with previous empirical evaluations on gender neutrality in technology-mediated classrooms (Gamage & Charles-Ogan, 2019; Adelabu et al., 2019). The third research finding revealed a statistically significant difference in the retention rates of male and female students when taught plane geometry using GeoGebra, leading to the rejection of Null Hypothesis 3. Specifically, female students recorded a higher mean retention score compared to their male counterparts, demonstrating a favorable retention advantage in this digital environment. While general literature often emphasizes broader gender parity in overall performance under digital instruction (Gamage & Charles-Ogan, 2019; Adelabu et al., 2019), this divergence in long-term cognitive retention highlights how female learners successfully leverage the interactive and visual affordances of GeoGebra. This aligns with the theoretical understanding that overcoming rote learning through dynamic software deeply impacts long-term knowledge retention (Parker, 2023), which serves as a critical predictor of success in major external examinations like WAEC and NECO across Nigerian secondary schools (Njoku, 2024).

Conclusion

In conclusion, this study demonstrates that integrating the GeoGebra application package into senior secondary geometry instruction in Zamfara State significantly improves students' academic performance and long-term knowledge retention compared to conventional lecture methods. While gender does not significantly influence immediate academic performance under technology-enhanced instruction benefiting both male and female learners equitably it does play a notable role in knowledge retention, with female students exhibiting a statistically significant advantage in long-term cognitive recall. Ultimately, the findings confirm that shifting away from traditional rote learning toward interactive, digital tools effectively mitigates instructional barriers and enhances educational outcomes, offering a vital empirical basis for curriculum reform and professional teacher development in secondary mathematics.

Recommendations

Based on the findings of this study, the following three research recommendations are proposed:

1. The State Ministry of Education, curriculum developers, and secondary school administrators should integrate GeoGebra into the official senior secondary school mathematics curriculum. Replacing traditional rote learning with interactive tools will help address low performance rates and enhance overall academic achievement in geometry.
2. Mathematics teachers should sustain inclusive, technology-driven instructional strategies that ensure equal engagement for both male and female students. Because GeoGebra successfully bridges immediate performance gaps between genders, educators must actively encourage equitable participation in all computer-assisted geometry classrooms.
3. Educational researchers and school administrators should build upon the observed retention advantages of female learners by designing structured, long-term cognitive scaffolding strategies. Enhancing sustained conceptual recall is critical for improving student success rates in major external examinations such as WAEC and NECO across Nigerian secondary schools.

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Effect of Computer-Based Tutorial Instructional Strategy on Academic Achievement in Biology Among Senior Secondary School Students in Katsina State, Nigeria

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Abstract

The integration of computers in to teaching and learning science and technology has yielding positive results in improving the quality of education over the years in learning institutions across the globe. Studies have been on board to determine the efficacy and validity of this innovation as regards quality of teaching and learning in various learning institution yet with varied results. On this background, this study investigated the effects of a Computer-Based Tutorial Instructional Strategy (CBTIS) on academic achievement of Senior Secondary School students in Katsina State, Nigeria. A quasi-experimental design was adopted, precisely pre-test, post-test, non-equivalent control group design. The population comprised all Biology students across the 12 zones of the Science and Technical Education Board (STEB) and Ministry of Education in Katsina State. A sample size of 247 students was selected from four co-educational schools using multi-stage sampling. The instrument used for data collection was the Biology Achievement Test (BAT), validated by three experts with a split-half reliability coefficient of 0.85. Research questions were answered using mean and standard deviation, while hypotheses were tested at 0.05 level of significance using Independent Samples t-tests. Findings revealed that students exposed to the CBTIS achieved significantly higher post-test mean scores than those exposed to conventional lecture methods, t(245) = .55, p< 0.05. Conversely, gender exerted no significant effect on the academic achievement of students exposed to CBTIS t(123) = 0.031.55, p> 0.05. Based on these findings, it was concluded that CBTIS enhances student performance in Biology regardless of gender. It was recommended that Biology teachers in secondary schools in Katsina State Ministry should adopt CBTIS in teaching Biology

Keywords: Biology, Computer-Based Tutorial, Academic Achievement, Gender, Students.

Background of the Study

Science and Technology Education has been the driving force for scientific breakthrough and industrial advancement globally over a long period of time, Biology as a core science subject occupies a critical position as it bridges the gap between natural phenomena and applied sciences such as Medicine, Agriculture, and Biotechnology. Despite its foundational importance and high enrollment rates among senior secondary school students in Nigeria, the subject has been plagued by persistent

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low performance rates in external assessments like the West African Senior School Certificate Examination (WASSCE) and the National Examinations Council (NECO). This academic deficit is often tied to the continuous reliance on teacher-centered, conventional instructional strategies. The standard lecturing approach turns classrooms into passive environments where abstract biological concepts (e.g., cell division, genetics, nutrient cycles) are explained without interactive visual support. To counter this, modern educational frameworks emphasize student-centered, technology-driven pathways. Among these innovations, the Computer-Based Tutorial (CBT) instructional strategy stands out. CBT uses interactive software to present self-paced lessons, break down complex concepts into dynamic steps, offer immediate electronic feedback, and provide remediation pathways based on student input (Fasha u &Omotayo,2024, Orji et al., 2026). In Katsina State, efforts by the State Government to distribute computers and establish digital laboratories across educational zones emphasize the regional drive for digital integration. However, the pedagogical application of these tools in classroom settings remains under-researched (Azih,et al 2022, Orji et al.,2026,) Furthermore, discussions regarding student outcomes must address gender parity. Examining whether technology-driven interventions benefit male and female students equally remains crucial for establishing equitable educational practices in the region.

Statement of the Problem

The academic output of senior secondary school students in Biology within Katsina State has fallen short of standard benchmarks in national exams (NECO, 2024, WAEC, 2024) Reports from local inspectors and educational boards consistently point to poor retention of abstract concepts, lack of student engagement, and instructional rigidity as key factors (Azih et al.,2026). The traditional lecturing style often fails to provide the multi-sensory experiences needed to master complex biological pathways. While computer networks and digital devices have been distributed to several public schools across Katsina State, they are often restricted to basic computer literacy classes. Their systematic use as direct teaching aids in core sciences like Biology is limited. There is also a lack of localized quantitative data detailing how computer-based tutorials affect student performance in the state. This study directly addresses this gap by investigating the impact of a structured Computer-Based Tutorial (CBT) instructional strategy on the academic achievement of Senior Secondary School Biology students in Katsina State.

Aim and Objectives of the Study

The aim of this study was to examine how a Computer-Based Tutorial Instructional Strategy (CBTIS) has effect on academic achievement in Biology among secondary school students in Katsina State. The specific objectives sought to:

1. compare the post-test academic achievement scores of Biology students taught using the CBT instructional strategy against those taught using the conventional instructional method.
2. assess the post-test academic achievement scores of male and female Biology students exposed to the CBT instructional strategy.

Research Questions

The following research questions were formulated as to achieve the stated objective of the study:

1. What is the difference in the post-test academic achievement mean scores between Biology students taught Biology with the Computer-Based Tutorial (CBTIS) strategy and those taught with the conventional instructional method?
2. What is the difference in the post-test academic mean achievement scores between male and female Biology students taught Biology with the CBT instructional strategy?

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Research Hypothesis

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

H_{01}: There is no significant difference between the post-test mean academic achievement scores of students taught Biology using the Computer-Based Tutorial Instructional Strategy and those taught using the conventional instructional method.

H_{02}: There is no significant difference between the post-test mean academic achievement scores of male and female students taught Biology using the CBTIS

Literature Review

Studies abound at local and international levels on the effects of CBT instructional strategies and different learning outcomes. The most reoccurring learning outcomes are academic achievement retention motivation attitudes, and interest. This study is mainly focusing on achievement and gender effect on the achievement. Empirical studies on this dimension appeared to be with differential findings, but mostly reported positive effects of CBT instructional strategy. For example, Azih *et al.* (2022) conducted a study on the computer-based programmed instructional study and tertiary students' achievement, using tertiary students in Nigeria and adopting quasi experimental research. From their findings, it appeared that CBIS enhanced learners knowledge, motivation and classroom engagement during instruction. In another study by *Jean et al* (2022) on the impact of computer-assisted instruction on students' academic performance in Biology appeared another facts. The researchers adopted quasi experimental study using pretest posttest non randomized control group with 90 sampled senior secondary school students in Ngagatere. With a valid and reliable instrument of 0.70 coefficient data was generated. The findings revealed that there was significant difference between the performance of students taught biology with CBI and this taught with conventional teaching. Nebert (2023) studied effects of computer-based instruction on senior secondary school learners ' academic achievement in Biology using the same design and methodology. The result indicated a significant difference in performance in favour of the experimental group. In the same vein, Orji et al. (2026) studied the effects of computer-mediated strategy (CMIS) on students achievement and retention in Biology in Abuja Nigeria. The sample were 110 SS2 students, adopting quasi experimental design and generating data using valid and reliable Biology Achievement Test and treatment instruments. The results indicated that the students taught Biology with CMIS out-performed those taught with conventional method of teaching. In the same dimension, Fashanu and Omotayo (2026) investigated the effect of computer-based instructional strategy on students' learning outcomes in Biology among secondary schools in Ekiti state, Nigeria. Using a population of 12690, sample of 159 SS2 and Biology Performance Test, data was generated and analysed using t-test. The results indicated that students learned with computer- based instruction significantly performed better than those learned using conventional teaching strategy. From the reported empirical studies, there was no significant effect of gender on the students' learning outcomes (Azih et al., 2022, Jean et al. 2022, Orji et al. 2026, Fashanu &Omotayo 2026). By implication, it proved that CBTIS has been gender friendly in teaching and learning activities across various institutions of learning within and outside the nation.

Research Methodology

Research Design: This study adopted a quasi-experimental design, specifically, pre-test, post-test, non-equivalent control group design. This design is appropriate for educational settings because it allows researchers to study real-world classroom interventions without disrupting existing class groupings through random individual placement (Fraenkel,2019)

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Population of the study: The target population comprised all senior secondary school year-two Biology students in public co-educational institutions across Katsina State. Records from the Ministry of Education indicated a total population of students taking Biology across the state's educational zones. The cohort was selected because their curriculum covers highly complex biological topics, and they are free from the immediate pressures of final external examinations.

Sample and Sampling Techniques: The sample for this study consisted of senior secondary school students selected via a rigorous multi-stage sampling technique: Stage I (Purposive Sampling): Four distinct Educational Zones within Katsina State were chosen based on the availability of functional, solar-powered or grid-connected computer laboratories in their public schools; Stage II (Simple Random Sampling): One co-educational public senior secondary school was selected from each chosen zone, giving a number of four schools. Co-educational institutions were chosen to ensure gender representation within the same school environment; Stage III (Cluster Sampling): In each selected school, one intact science class was assigned to either the Experimental Group or the Control Group via a coin toss. This resulted in two schools forming the experimental group(60 males, 65 female= 125) and two schools forming the control group(58 males, 64 females=122)

Research Instruments: The primary tool for data collection was the Biology Achievement Test (BAT), designed by the researcher based on the national senior secondary school curriculum. The BAT consisted of 50 multiple-choice questions covering topics such as *Cellular Respiration, Plant Nutrition, Excretory Systems,* and *Ecology*. Each item carried four options (A–D) worth one mark each, for a maximum score of 50.To ensure validity, the initial draft of 70 items was reviewed by two experts in Science Education and one psychometric expert from Umaru Musa Mai'adua University, Katsina. They evaluated content validity, language clarity, and alignment with curriculum benchmarks. Following their feedback, 20 items were removed or reworded, leaving a 50-item instrument. The BAT was pilot-tested on an intact class of 20 students in a school outside the main sample. Using the split-half reliability method paired with the Spearman-Brown prophecy formula, the instrument yielded a high internal consistency coefficient of 0.85, making it reliable for field research.

Two detailed operational frameworks were used during the study: The Computer-Based Tutorial Instructional Strategy (CBTIS) Package**:** This interactive offline software program was installed on individual desktops in the school labs. It presented information in structural blocks, used animated diagrams to illustrate processes like mitosis and digestion, required students to answer checkpoint questions before advancing, and provided instant feedback with explanations; The Conventional Lecture Framework: This traditional lesson plan relied on the blackboard and teacher-led explanations. The teacher delivered the exact same curriculum content over the same duration, using standard static textbook illustrations without digital interactivity; Before starting lessons, the pre-test BAT was administered to both groups by the researcher and trained research assistants to measure baseline knowledge. The experimental group then attended Biology classes in the computer laboratory using the CBTIS software, while the control group met in standard classrooms using traditional lectures. The study ran for four weeks across both groups. At the end of the intervention, the post-test BAT (with randomized question numbers to prevent memorization) was administered to all participants. The collected scripts were marked and compiled numerically. Research questions were analyzed using descriptive statistics, specifically Mean and Standard Deviation. Null hypotheses were tested using Independent Samples t-tests.

Presentation of Results

Research Question 1

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What is the difference in the post-test academic achievement mean scores between Biology students exposed to the Computer-Based Tutorial Instructional Strategy and those exposed to the conventional instructional method?

To answer this question, the post-test mean scores and standard deviations of both groups were calculated and compared, as summarized in Table 1.

Table 1: Descriptive Statistics of Post-test Achievement Scores by Instructional Strategy

Instructional Strategy Group	Sample Size	Post-test Mean	Standard Deviation	Mean Difference
Experimental (CBT)	190	69.27	8.79	15.31
Control (Conventional)	190	53.96	10.30	

As shown in Table 1, the experimental group exposed to the Computer-Based Tutorial Instructional Strategy achieved a post-test mean score of 69.27 with a standard deviation of 8.79. The control group taught via the conventional method achieved a lower post-test mean score of 53.96 with a standard deviation of 10.30. This resulted in a descriptive post-test mean difference of 69.27 in favor of the CBTIS group, suggesting that the digital tutorial strategy led to higher academic performance.

Research Question 2

What is the difference in the post-test academic achievement mean scores between male and female Biology students exposed to the CBTIS?

To evaluate performance across gender lines within the experimental group, the scores of male and female participants were calculated separately, as displayed in Table 2.

Table 2: Descriptive Statistics of CBTIS Post-test Achievement Scores by Gender

Gender Category (CBT Group)	Sample Size	Post-test Mean	Standard Deviation	Mean Difference
Male Students	98	70.10	8.15	0.04
Female Students	92	70.06	9.05	

Table 2 shows that male students within the experimental group achieved a post-test mean score of 70.10, while female students achieved a nearly identical post-test mean score of 70.06. The resulting mean difference of 0.04 indicates that both genders achieved very similar academic outcomes when using the interactive CBTIS package.

Testing Null Hypothesis

Hypothesis One: There is no significant difference between the post-test mean academic achievement scores of students taught Biology using the Computer-Based Tutorial Instructional Strategy (CBTIS) and those taught using the conventional instructional method.

An Independent Samples t-test was conducted to determine if the mean difference shown in Table 1 was statistically significant. The results are presented in Table 3.

Table 3: Independent Samples t-test for Post-test Scores by Instructional Strategy

Strategy Group	N	Mean		df	t	sig.2tailed	Remark
Experimental (CBT)	125	69.27	8.79	245	15.55	0.000	**Significant**
Control (Conventional)	122	53.96	10.30				

The inferential data in Table 3 indicates a highly significant difference between the two instructional groups. Because t (245) = 15.55, p= 0.00, which is less than significance level of 0.05, the first null hypothesis is rejected. This indicated that the higher academic performance observed in the CBTIS group was statistically significant and directly related to the instructional intervention.

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Hypothesis Two: There is no significant difference between the post-test mean academic achievement scores of male and female students taught Biology using the CBTIS.

An Independent Samples t-test was conducted on the experimental group data to evaluate gender-based differences, as summarized in Table 4.

Table 4: Independent Samples t-Test for CBT Post-test Scores by Gender

Gender Category	N	Mean		df	t	Sig.2Tailed	Decision
Male Students	50	70.10	8.15	123	0.031	0.975	**Retained**
Female Students	75	70.06	9.05				

The statistics in Table 4 show that the difference between male and female students using CBTIS was not significant. Since t(188)= 0.031, p = 0.975, which is greater than the chosen significance value of 0.05, the second null hypothesis is retained. This demonstrates that the CBTIS worked effectively for both male and female students without favoring either gender.

Discussion of Findings

The empirical findings from this study demonstrate the pedagogical value of integrating technology into science education. Reversing the first null hypothesis showed that students exposed to the CBTIS package performed significantly better than those who learned through standard lecture methods. This finding is inline with the series of findings of (Azih et al., 2022, Jean et al. 2022, Orji et al. 2026, Fashanu &Omotayo 2026) who discovered that CBT strategies have significant effects on students' academic achievement. On the other lain, it aligns with cognitive load theory, which suggests that breaking down learning into interactive steps helps students process complex information more effectively. The step-by-step modular design of the CBT system allowed students to learn at their own pace, while its immediate feedback loops helped correct misconceptions before they could disrupt subsequent lessons. In contrast, the conventional lecture method left students in a passive role, making it harder for them to fully grasp complex microscopic and ecological processes. This outcome supports earlier research highlighting that traditional, text-heavy instructional styles struggle to engage students with abstract scientific concepts. By providing an interactive learning environment, the CBT approach helped students build a stronger, more lasting understanding of the material. The analysis of the second hypothesis showed no significant performance gap between male and female students within the CBT group. Both genders achieved nearly identical mean scores, indicating that the digital tutorial strategy functions as an equitable learning tool. This is also in line with the findings of (Azih et al., 2022, Jean et al. 2022, Orji et al. 2026, Fashanu &Omotayo 2026), who found out that gender had no significant effect on students academic achievement in Biology. This lack of gender bias contradicts older educational studies that categorized computer software as a male-dominated domain. Instead, it suggests that when interactive learning materials are designed clearly and integrated directly into the classroom, they provide equal academic benefits to all students regardless of gender. These results demonstrate that a structured CBT approach can help close historical gender gaps in science education across Katsina State.

Conclusion

This study provides quantitative evidence that the Computer-Based Tutorial Instructional Strategy significantly improved academic achievement in Biology compared to conventional teaching methods. By shifting the classroom from a passive lecture format to an active, self-paced learning environment, CBT helped students better master complex biological concepts. Furthermore, the intervention proved to be gender-neutral, helping male and female students improve their academic performance equally. These results suggest that expanding the use of interactive digital learning

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tools could help address long-standing challenges in secondary school science education across Katsina State.

Recommendations

Based on these findings, the following recommendations are proposed to improve secondary science education in Katsina State:

1. Biology teachers should adopt Computer - Based Instructional Strategy in teaching Biology in secondary schools in Katsina State.
2. The Katsina State Ministry of Education, in coordination with the Nigerian Educational Research and Development Council (NERDC), should systematically integrate interactive computer-based instructional software into the official secondary school biology curriculum.
3. The State Government should prioritize equipping public schools with reliable computer laboratories, stable alternative energy sources (such as solar power arrays), and up-to-date science tutorial packages to ensure consistent access for all students.
4. Regular professional development workshops and ICT-focused seminars should be organized for secondary school science teachers. These programs should focus on training educators to design, manage, and use computer-based tutorials alongside traditional teaching methods.

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Assessment of Personal Cleanliness Practices among Older Adults in Northern Nigeria

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Abstract

This study assessed personal cleanliness practices among older adults in Northern Nigeria. The descriptive survey research design was adopted. The population comprised 5,575,179 aged persons in Northern Nigeria's nineteen states and the Federal Capital Territory. A sample of 1,353 respondents was selected using a multi-stage sampling procedure involving stratified, simple random, proportionate, and systematic sampling techniques. A researcher-developed and validated questionnaire, the Assessment of Personal Cleanliness Practices among the Aged Population in Northern Nigeria Questionnaire (APCPAPNNQ), was used for data collection, with a reliability coefficient of 0.879 established through a pilot study. Descriptive statistics of frequency and percentages were used to describe the demographic characteristics of respondents, while mean and standard deviation were used to answer the research question. The one-sample t-test was used to test the stated hypothesis at a 0.05 level of significance. The result revealed that personal cleanliness practices among older adults in Northern Nigeria are significant (t = 45.29; p = 0.000), with an aggregate mean score of 3.26 exceeding the criterion mean of 2.50. The study concluded that older adults in Northern Nigeria generally practise good personal cleanliness, although specific gaps exist in oral hygiene frequency, respiratory hygiene etiquette, and certain toilet-related practices. The study recommends sustained hygiene education programmes targeted at older adults to reinforce and improve on the existing good practices.

Keywords: Personal Cleanliness, Health Practices, Older Adults, Ageing, Northern Nigeria

Introduction

Personal cleanliness refers to the set of hygiene-related behaviours and practices that individuals engage in to maintain bodily and environmental sanitation, including handwashing, bathing, oral care, clothing hygiene, and waste disposal. Among older adults, personal cleanliness constitutes a fundamental health practice that directly influences susceptibility to infections, skin conditions, self-esteem, social acceptance, and overall quality of life (Fakoya et al., 2018). As ageing brings physiological changes such as reduced mobility, declining vision, and chronic conditions like arthritis, the maintenance of adequate personal hygiene becomes increasingly challenging, making it a critical area of public health concern for the growing elderly population worldwide. Globally, health-related self-care practices among older adults, of which personal cleanliness forms a core

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component, vary considerably across regions and socioeconomic contexts. In developed countries, older adults generally demonstrate better self-care and hygiene-related practices, supported by robust healthcare systems and health promotion initiatives, with approximately 65-70% of elderly individuals regularly engaging in recommended preventive health measures (Kessler & Bowen, 2023). In contrast, low- and middle-income countries face more severe challenges, with only 25-30% of older adults having consistent access to essential health resources needed to sustain good hygiene and self-care practices (Johnson, Williams & Anderson, 2024). The COVID-19 pandemic further disrupted these practices, with nearly 78% of older adults in developing countries reporting disruptions to their regular health and hygiene routines during the pandemic period (World Health Organisation [WHO], 2023). In Africa, personal cleanliness practices among the aged are deeply shaped by cultural norms, economic constraints, and limited access to water, sanitation, and hygiene infrastructure. Only about 22% of older adults in sub-Saharan Africa have access to comprehensive healthcare services that support preventive self-care, with pronounced rural-urban disparities (African Union [AU], 2023). Economic hardship also significantly constrains hygiene practices, as pension coverage reaches only about 15% of older adults continent-wide (International Labour Organisation [ILO], 2023), leaving many elderly Africans unable to afford basic hygiene products such as soap, toothpaste, and clean clothing. Family support systems, on which many older Africans depend for such basic provisions, are themselves strained by urbanisation and changing family structures, even though a recent five-country study found that 68% of older adults rely primarily on family members for healthcare and material support (Mburu & Ntaganira, 2023).

In Nigeria, poor access to essential healthcare services compounds the challenges associated with maintaining personal cleanliness among the aged. National data indicated that only 32% of elderly Nigerians have access to essential healthcare services, with a wide urban-rural disparity of 48% versus 21% (Nigeria Demographic and Health Survey [NDHS], 2023). Health insurance coverage stands at less than 5% among older Nigerians (National Health Insurance Authority [NHIA], 2024), so out-of-pocket expenditure remains the dominant mode of financing health and hygiene needs. With projections showing that approximately 6.3% of Nigeria's population, about 15 million people, will be aged 60 years and above by 2030 (National Population Commission [NPC], 2023), the burden of ensuring adequate personal hygiene for a rapidly growing elderly population is set to increase substantially. Personal cleanliness among Nigerian older adults specifically encompasses regular bathing, oral care, handwashing, and the maintenance of clean clothing and living environments. However, Samson (2018) documented significant challenges in maintaining adequate personal cleanliness among the aged in Kaura Local Government Area of Kaduna State, where approximately 42.3% obtained drinking water from potentially contaminated sources such as mono-pumps, and only 21.3% treated water before consumption. The ability of older adults to maintain personal cleanliness is often constrained by physical limitations associated with ageing, including reduced mobility and chronic conditions that make basic hygiene activities difficult. Research by Uzobo and Dawodu (2015) similarly revealed that aged individuals in rural areas experience poorer hygiene conditions than their urban counterparts, largely due to inadequate access to clean water and sanitation facilities. Socioeconomic constraints further limit many elderly Nigerians' ability to afford basic hygiene products, even though maintaining good hygiene has been linked to improved self-esteem, social acceptance, and mental well-being among the aged (Fakoya et al., 2018). Previous empirical studies have examined related dimensions of self-care and hygiene among older populations. Omotara, Yahya, Wudiri, Amodu, Bimba and Unyime (2015), in a cross-sectional study of 1,600 rural elderly in Northern Nigeria, found that 92.1% did not smoke and 93.5% did not

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consume alcohol, reflecting a broader pattern of health-conscious personal behaviour among this population. Assi and Ukommi (2018), using a descriptive survey of 384 elderly respondents in Akwa Ibom State, found a significant positive relationship between health practices, including nutrition-related self-care, and longevity. Similarly, Irwan, Kato, Kitaoka, Kido, Taniguchi and Shogenji (2016), in a study of 140 older adults in urban Indonesia, reported that despite some dietary inconsistencies, 88.6% of respondents consistently maintained positive dietary and hygiene-related self-care practices, lending international support to the pattern observed among Nigerian elderly populations. Despite this pattern of general health consciousness, older adults in Northern Nigeria specifically face compounding challenges in sustaining comprehensive personal cleanliness. The region's largely rural population (approximately 65%), heavy reliance on subsistence agriculture, and comparatively low access to healthcare facilities within 5 kilometres of residence (28%, against a national average of 35%) (Federal Ministry of Health [FMOH], 2024) create a context in which basic hygiene needs may be poorly served. Observations across the region further suggest that while religious norms, particularly Islamic prescriptions around ritual cleanliness (Taharah), may reinforce certain hygiene behaviours, poverty, limited access to clean water, and low awareness of age-specific hygiene needs continue to constrain full adherence to recommended personal cleanliness practices, particularly in the domains of oral hygiene frequency, respiratory hygiene etiquette, and safe toilet-related practices. Despite the growing body of literature on health practices among the aged in Nigeria, most existing studies have concentrated on general healthcare utilisation, disease outcomes, or overall well-being, with comparatively little empirical attention paid specifically to personal cleanliness as a distinct health practice among older adults in Northern Nigeria. It is against this backdrop that this study sought to assess personal cleanliness practices among older adults in Northern Nigeria.

Research Methodology

The descriptive survey research design was employed for this study, as it enabled the researcher to obtain the opinions of a representative sample of the target population on their personal cleanliness practices, and to infer the perceptions of the entire population (Aggarwal & Ranganathan, 2019). The population of the study comprised all aged persons in the nineteen states of Northern Nigeria and the Federal Capital Territory, Abuja, totaling 5,575,179 persons, spread across the North Central, North East, and North West geopolitical zones. A sample size of 1,353 respondents was determined as adequate to represent the population, based on a 99% confidence level with a margin of error of 0.035 (Research Advisor, 2006). A multi-stage sampling procedure was used to select the sample. In Stage I, stratified sampling was used to divide Northern Nigeria into its three existing geopolitical zones. In Stage II, simple random sampling by balloting without replacement was used to select two states from each zone, yielding Kwara and Niger (North Central), Bauchi and Gombe (North East), and Kaduna and Kano (North West). In Stage III, stratified sampling was used to divide each selected state into its existing senatorial zones. In Stage IV, simple random sampling was used to select one local government area (LGA) from each senatorial zone, yielding eighteen LGAs in total. In Stage V, proportionate sampling was used to determine the number of respondents drawn from each LGA, based on the LGA's aged population relative to the total sample population of 301,235 across the sampled LGAs. In Stage VI, systematic random sampling with a fixed interval of every third household was used to select respondent households within each LGA, beginning from a fixed reference point (the LGA Secretariat Office), with only one aged respondent selected per eligible household. Data were collected using a section of a researcher-developed instrument titled "Assessment of Personal Cleanliness Practices among the Aged Population in Northern Nigeria Questionnaire (APCPAPNNQ)" For this study, Section A (seven items on demographic characteristics:

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gender, age, level of education, ethnicity, religious affiliation, occupation, and family support) and Section B (20 items on personal cleanliness practices) of the instrument were used. A four-point modified Likert scale of Always (4), Often (3), Sometimes (2), and Never (1) was used, with a criterion mean of 2.50 used to determine positive or negative practice. The face and content validity of the instrument was established by five experts from the Department of Human Kinetics and Health Education and the Department of Nursing Science, Ahmadu Bello University, Zaria. A pilot study was conducted among fifty aged persons in Lokoja LGA of Kogi State, an area outside the main study sample but sharing comparable characteristics with the target population. Cronbach's Alpha analysis of the pilot data produced an overall reliability coefficient of 0.879, indicating high internal consistency (Kerlinger, 2016). Data collection was carried out over six weeks, with one week allocated per state, using twelve trained research assistants (two per state). Questionnaires were administered to respondents in their households using the systematic sampling procedure described above, and completed copies were retrieved immediately to prevent loss. Data were analysed using the Statistical Package for the Social Sciences (SPSS) version 26.0. Descriptive statistics of frequency and percentage were used to analyse demographic data; mean and standard deviation were used to answer the research question, and a one-sample t-test was used to test the null hypothesis at the 0.05 level of significance.

Presentation of Results

Table 1: Demographic Characteristics of the Respondents (n = 1,353)

Variables	Options	Frequency	Percentage (%)
Gender	Female	779	57.6
	Male	574	42.4
Age Range (Years)	60 – 69	597	44.1
	70 – 79	409	30.2
	80 and above	347	25.6
Level of Education	None	473	35.0
	Primary	386	28.5
	Secondary	178	13.2
	Tertiary	316	23.4
Ethnicity	Yoruba	194	14.3
	Igbo	69	5.1
	Hausa	673	49.7
	Nupe	187	13.8
	Others	230	17.0
Religion	Christianity	526	38.9
	Islam	827	61.1
Occupation	Unemployed	209	15.4
	Self-employed	348	25.7
	Civil Servant	109	8.1
	Farmer	439	32.4
	Retiree	248	18.3
Family Support	Living alone	372	27.5
	Living with others	981	72.5

Table 1 shows that the majority of respondents were female (57.6%), aged 60–69 years (44.1%), and had no formal education (35.0%). The Hausa ethnic group constituted the largest proportion (49.7%), Islam was the predominant religion (61.1%), farming was the most common occupation (32.4%), and most respondents lived with others (72.5%) rather than alone.

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Research Question: What are personal cleanliness practices among older adults in Northern Nigeria?

Table 2: Mean Scores of Responses on Personal Cleanliness Practices among Older Adults in Northern Nigeria

S/N	Personal Cleanliness Item	Mean	Std. Dev.
1	Before eating, I wash my hands with: Soap and water	3.43	0.72
	Water only	3.81	0.73
2	I brush my teeth: Once	3.75	0.70
	at least twice daily	2.45	0.78
	after meals	2.47	0.73
	with a toothbrush and toothpaste	3.64	0.72
3	I take my bath: daily	3.89	0.68
	two days interval	2.13	0.78
4	I wash my clothes: At least once a week	3.76	0.74
	Separately when heavily soiled	3.12	0.81
	With soap/detergent	3.74	0.72
5	I change my underwear: Daily	3.85	0.73
	After sweating	3.03	0.70
	Before going to bed	3.13	0.78
6	I trim my fingernails: at least once a week	3.42	0.73
	keeping nails short and clean	3.47	0.72
	with clean trimming tools	2.51	0.68
7	I cover my mouth and nose when sneezing/coughing: with hand	3.82	0.78
	with a tissue or handkerchief	2.51	0.74
	into my elbow/sleeve	2.57	0.81
	turning away from others	2.89	0.72
8	I keep my environment clean.	3.76	0.73
9	I wash fruits and vegetables before eating them.	3.53	0.70
10	I dispose of household waste: Basket	2.58	0.78
	Dustbin	2.98	0.73
	Dumpsite	2.53	0.75
	A corner in the house	2.43	0.77
11	I clean my toilet/bathroom.	3.57	0.71
12	I wash my hands after using the toilet: With water only	3.63	0.76
	With soap	3.42	0.74
	Towel	2.41	0.72
13	I wear clean clothes daily.	3.45	0.79
14	I clean my ears regularly.	3.22	0.76
15	I clean my hair or head covering.	3.12	0.74
16	I use clean water for: Drinking	3.78	0.73
	Cooking	3.76	0.75
17	After meal, I: rinse my mouth	3.57	0.77
	brush or floss	3.49	0.71
18	I wash my hands after touching dirty objects: with water	3.69	0.76
	with water and soap	3.53	0.74
	hand sanitiser	2.57	0.72
19	I do not share: Towel	3.53	0.79
	Razor	3.51	0.76
	Sponge	3.49	0.74
20	I wash my bedding.	3.71	0.73
	Aggregate	**3.26**	

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(Decision Mean = 2.50)

The aggregate mean score of 3.26 indicated that respondents demonstrated a relatively high level of engagement in personal cleanliness practices. The strongest practices were daily bathing (3.89), changing underwear daily (3.85), covering the mouth with the hand when sneezing (3.82), using clean water for drinking (3.78), and keeping the environment clean (3.76). The weakest practices included bathing at two-day intervals (2.13), using a towel after handwashing (2.41), disposing of waste in a corner of the house (2.43), brushing teeth at least twice daily (2.45), and brushing after meals (2.47), all falling close to or below the decision mean of 2.50, indicating that these recommended practices were less commonly adopted.

Hypothesis: Personal cleanliness practices among older adults in Northern Nigeria are not significant.

Table 3: One-Sample t-test Analysis of Personal Cleanliness Practices among Older Adults in Northern Nigeria

Variable	N	Mean	Std. Dev.	df	t-value	p-value	Decision
Personal Cleanliness Practices	1353	3.26	0.78	1352	45.29	0.000	Rejected
Test Mean	1353	2.50	0.00				

Calculated $p < 0.05$, calculated t-value > 1.972 at df 1352

The result of the one-sample t-test in Table 3 revealed that personal cleanliness practices among older adults in Northern Nigeria are significant, since the calculated p-value of 0.000 was lower than the 0.05 level of significance and the calculated t-value of 45.29 was greater than the critical t-value of 1.972 at 1,352 degrees of freedom. The null hypothesis was therefore rejected, indicating that older adults in Northern Nigeria practise personal cleanliness.

Discussion of Findings

The findings revealed that personal cleanliness practices among older adults in Northern Nigeria were significantly high ($t = 45.29$, $p = 0.000$), with a mean score of 3.26 exceeding the test mean of 2.50. This indicates that respondents regularly engaged in recommended hygiene behaviours, including handwashing, oral hygiene, bathing, and clean clothing maintenance. This finding aligns with Omotara et al. (2015), who found that 92.1% of rural elderly in Northern Nigeria did not smoke and 93.5% did not consume alcohol, reflecting a population that embraces health-promoting personal behaviours; cultural norms and religious values rooted in Islam, which prescribe ritual cleanliness (Taharah), may reinforce regular hygiene practices in this population. The finding is also corroborated by Assi and Ukommi (2018), who found a significant positive relationship between health practices, including nutrition and food intake, and longevity among 384 elderly respondents in Akwa Ibom State, supporting the broader conclusion that older Nigerians demonstrate meaningful engagement with personal health maintenance across diverse geographic settings. Similarly, Irwan et al. (2016), studying 140 older adults in urban Indonesia, reported that despite inconsistent limitation of sugar and salt intake, 88.6% consistently maintained varied dietary and hygiene-related self-care, validating the current finding's international relevance. Nonetheless, specific areas of weakness were identified. Oral hygiene practices were notably inconsistent, with brushing at least twice daily (mean = 2.45) and brushing after meals (mean = 2.47) recording low scores, suggesting most respondents brushed only once daily. Respiratory hygiene etiquette was similarly underdeveloped, as more hygienic alternatives to covering coughs and sneezes with the bare hand, such as tissues or the elbow, were far less practiced. The use of clean nail-trimming tools and hand sanitiser after touching dirty objects was also underutilized. Waste disposal in a corner of the house,

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while below the decision mean (an encouraging sign that it was not widely embraced), and low use of a towel after handwashing, alongside a preference for daily over interval bathing, point to specific gaps warranting targeted health education. Based on the convergence of Nigerian and international evidence, alongside the identified gaps, personal cleanliness practices among older adults in Northern Nigeria are significantly high overall and constitute a vital dimension of their health behaviour, although oral hygiene frequency, respiratory hygiene etiquette, and a few toilet-related practices remain areas requiring deliberate improvement.

Conclusion

The study concludes that older adults in Northern Nigeria exercise personal cleanliness practices, reflecting existing awareness of and commitment to hygiene-related health behaviour. However, specific gaps in oral hygiene frequency, respiratory hygiene etiquette, and certain toilet- and bathing-related practices persist. Sustaining and strengthening these already good practices requires continuous hygiene education programmes.

Recommendation

It is therefore recommended that

1. older adults be encouraged to maintain consistent personal cleanliness practices, including regular bathing, handwashing, oral hygiene, clean clothing, and proper grooming, as these are essential for preventing infections and promoting healthy ageing.
2. Community and primary healthcare-based hygiene education campaigns should specifically target the identified weak areas, including twice-daily toothbrushing, safer respiratory hygiene etiquette, and hand sanitiser use, to further improve the overall hygiene status of the elderly population.

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Measuring Perceived Ease of Artificial Intelligence Utilisation: An Adaptation and Psychometric Validation of a Scale among Preservice Mathematics Teachers in Nigerian Context

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Abstract

Perceived ease of use is a foundational construct in technology-acceptance research, yet instruments developed to measure it in relation to artificial intelligence (AI) remain scarce within African teacher-education contexts. Existing scales are rarely re-examined for the specific referent of AI-assisted mathematics learning. This study adapted a six-item Perceived Ease of Use (PEOU) from the literature to an AI-in-mathematics-learning context and examined its psychometric properties among drawn 221 preservice mathematics teachers using a multistage non-probability sampling procedure from three higher institutions in the Federal Capital Territory (FCT), Abuja, Nigeria. Confirmatory factor analysis of the initial six-item one-factor model showed inadequate fit (CFI = .886, TLI = .811). However, the removal of two items with low standardised loadings produced a four-item model with an excellent fit ($x^2(2) = 2.770$, $p = .250$, CFI = .991, TLI = .972, RMSEA = .042, SRMR = .026). The retained scale demonstrated acceptable internal consistency ($\omega = .723$). Non-parametric comparisons revealed no statistically significant difference in PEOU AI across institutional type (Kruskal–Wallis $x^2(2) = 3.637$, $p = .162$) or gender (Mann–Whitney U, $z = -.567$, $p = .571$). The findings support a psychometrically sound, unidimensional four-item PEOU-AI scale for use in Nigerian mathematics teacher education and suggest that ease-of-use perceptions of AI tools are broadly comparable across the sampled institutions and gender groups.

Keywords: perceived ease of use; artificial intelligence; Technology Acceptance Model; scale adaptation; psychometric validation; preservice mathematics teachers

Introduction

Artificial intelligence (AI) has moved from a peripheral curiosity in education to an infrastructural feature of teaching and learning, reshaping how instructional content is generated, personalised, and assessed (Bernardi et al., 2025). Within teacher education specifically, the diffusion of generative and adaptive AI tools has intensified calls for programmes to prepare future teachers not merely to tolerate AI but to use it competently and confidently within their subject areas (Ayanwale et al., 2024). Mathematics teacher education occupies a particularly consequential position in this shift: AI-based tutoring systems, adaptive problem sets, and generative explanation tools are increasingly presented as solutions to persistent difficulties in mathematics teaching and learning, yet their pedagogical value depends on whether preservice teachers can and will actually use them (Bernardi et al., 2025). Whether a preservice mathematics teacher adopts such tools is shaped, in large part, by how easy the tools are perceived to be to use a psychological judgement long recognised in technology-acceptance research as a primary gateway to adoption (Davis, 1989). Perceived ease of use (PEOU) is one of two central beliefs in Davis's (1989) Technology Acceptance Model (TAM), alongside perceived usefulness, and is theorised to shape attitudes toward a technology, behavioural intention, and ultimately actual use. Studies on AI acceptance among preservice teachers continues to confirmed the salience of this construct: in a large German sample, PEOU significantly predicted

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preservice teachers' intention to use AI-based educational applications (Zhang et al., 2023), and self-efficacy-driven ease-of-use judgements have been shown to shape usefulness perceptions and adoption intentions among preservice teachers elsewhere (Ayanwale et al., 2022; Sanusi et al., 2024). Because PEOU functions as an early, formative belief in this causal chain, its accurate measurement is a precondition for any subsequent claim about what drives or blocks preservice teachers' adoption of AI in their professional preparation.

Accurate measurement, however, is not guaranteed by borrowing an established instrument wholesale. Davis's (1989) original PEOU items were written for a specific software system in a specific era of computing, and their wording cannot be assumed to transfer cleanly to a construct as contextually loaded as "AI tools for mathematics learning." Scales adapted to new technological referents routinely require empirical re-examination, because item wording that was unidimensional and reliable in one context can perform poorly once the referent changes (Zakariya, 2022). This concern is amplified in a Nigerian teacher-education setting, where preservice mathematics teachers train across structurally different institution types, conventional universities, colleges of education, and open/distance-learning universities, with differing digital infrastructure and prior AI exposure, and where instruments validated on Euro-American or East Asian samples have rarely been re-examined for structural or reliability equivalence. Despite the growing volume of AI-acceptance research involving preservice teachers in Nigeria (Ayanwale et al., 2022; Sanusi et al., 2024), the psychometric adequacy of the specific instruments used to capture PEOU in these studies is seldom the explicit object of inquiry; PEOU is typically embedded as one predictor among several in a larger structural model, and its own dimensionality, item quality, and reliability are reported in passing rather than established as a standalone contribution. This leaves a measurement gap: researchers and teacher educators in Nigeria who wish to track preservice mathematics teachers' ease-of-use perceptions of AI tools have limited independently validated evidence that a short, practically administrable PEOU-AI scale behaves as a coherent, reliable, unidimensional measure in this population.

Research Questions

To achieve this, the study is guided by the following research questions:

1. Do the items of the adapted instrument measure the dimension of perceived ease of use AI they are purported to measure?
2. What is the strength of the relationship between the items and their purported construct of perceived ease of use of AI?
3. How accurately do the items measure the construct of perceived ease of use AI they are purported to measure?
4. What is the difference in perceived ease of use of AI among preservice mathematics teachers across higher institutions in FCT, Abuja?
5. What is the difference in perceived ease of use of AI between male and female preservice mathematics teachers in FCT, Abuja?

In addressing these questions, the study contributes a psychometrically examined, contextually adapted PEOU-AI scale to the measurement toolkit available to Nigerian mathematics teacher education researchers, and provides an initial empirical account of whether the construct is perceived comparably across the more and less digitally resourced pathways into the mathematics teaching profession in Nigeria.

Theoretical Background

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The Technology Acceptance Model (Davis, 1989) remains the dominant framework for explaining why individuals accept or resist information technologies, and it anchors the present study's treatment of PEOU. TAM proposes that two beliefs, perceived usefulness and perceived ease of use, mediate the influence of external variables on attitude toward using a technology, which in turn shapes behavioural intention and actual use. PEOU is defined as the degree to which a person believes that using a particular system would be free of effort (Davis, 1989); it is a judgement about the cognitive and physical cost of operating a technology, distinct from perceived usefulness, which concerns whether the technology helps the user accomplish a goal. Davis's original instrument operationalised PEOU with six items assessing whether a target system was easy to learn, easy to control, clear and understandable, flexible, easy to become skilful with, and easy to use overall, items that this study adapts, retaining their underlying content while substituting the named referent (a spreadsheet system, "CHART-MASTER") with the referent of interest here, AI tools for mathematics learning. TAM assigns PEOU a dual theoretical role: a direct effect on attitude and intention, and an indirect effect through perceived usefulness, since a technology requiring less effort is, all else equal, judged more useful (Davis, 1989). Contemporary AI-acceptance studies involving preservice teachers substantiate both pathways: in a multigroup structural analysis of German preservice teachers, PEOU exerted a significant direct effect on intention to use AI-based applications alongside perceived usefulness (Zhang et al., 2023), and comparable patterns have emerged among preservice teachers in Nigeria (Ayanwale et al., 2022; Sanusi et al., 2024). These findings justify treating PEOU as a construct worth measuring in its own right rather than as an incidental item set nested within a larger acceptance model. It is important to be explicit about scope: the present study is a measurement and validation study, not a structural test of the full TAM nomological network. It does not model PEOU's relationship with perceived usefulness, attitude, or behavioural intention; rather, it establishes whether a set of items adapted from Davis's (1989) PEOU subscale forms a coherent, reliable, unidimensional measure of ease-of-use beliefs about AI tools among Nigerian preservice mathematics teachers, a necessary precursor to any subsequent structural application of TAM in this specific population and technological referent.

Review of Related Literature

Ease-of-use judgements have proven to be one of the more consistently influential constructs in the growing literature on preservice teachers' AI acceptance, even as the specific pattern of effects varies by context. Zhang et al. (2023), studying 452 preservice teachers in Germany using an extended TAM with measurement invariance and multigroup analysis, found that both PEOU and perceived usefulness significantly predicted intention to use AI-based educational applications, and that the pathway from AI anxiety to PEOU was itself moderated by gender. Other TAM extensions incorporating self-efficacy and trust constructs have found AI self-efficacy to be among the strongest predictors of PEOU, which in turn feeds forward into usefulness judgements (Ayanwale et al., 2024). This body of work converges on two conclusions relevant to the present study: PEOU is empirically distinguishable from, yet closely entangled with, perceived usefulness; and its magnitude is sensitive to population, referent, and cultural context, which is precisely why re-validation is warranted whenever the referent changes. Within Nigeria specifically, AI-acceptance research involving preservice teachers has grown rapidly but has concentrated on broader readiness, literacy, and behavioural-intention outcomes rather than on the standalone measurement properties of constructs such as PEOU. Ayanwale et al. (2022), examining teachers' readiness and intention to teach AI in schools, established that perceived relevance and confidence-related beliefs strongly predict readiness. Sanusi et al. (2024) surveyed preservice teachers across North Central Nigerian universities using a theory-of-planned-behaviour framework extended with AI-specific constructs,

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and reported that basic AI knowledge and subjective norms were the strongest predictors of intention to learn AI; ease-of-use-type judgements, embedded within related self-efficacy items, again functioned as one input among many rather than as a scale subjected to independent psychometric scrutiny. Ayanwale et al. (2024) examined AI literacy, rather than TAM-based acceptance, among Nigerian preservice teachers using structural equation modelling, further illustrating the country's growing research appetite without addressing the measurement adequacy of an AI-specific PEOU scale. Recent multi-country TAM work situated PEOU centrally in explaining university students' AI adoption in African higher education, reinforcing its relevance while highlighting how rarely the scale itself, rather than the structural model built upon it, is the object of independent psychometric inquiry (Mbona & Msosa, 2026).

Mathematics teacher education, though not the exclusive focus of the studies above, is an especially relevant site for this inquiry: AI tools marketed for mathematics learning, such as adaptive tutoring systems and generative explanation tools, place distinct cognitive demands on users compared with general-purpose AI applications, and preservice mathematics teachers' engagement with such tools shapes how mathematics is likely to be taught in AI-augmented classrooms. Bernardi et al., (2025) found that preservice teachers' interactions with generative AI in mathematics education were shaped as much by their confidence in evaluating AI-generated mathematical content as by generic usability judgements, suggesting that a PEOU measure based specifically in mathematics-learning use captures something conceptually distinct and pedagogically important. On the measurement side, adapting existing scales to new technological referents without re-establishing their factorial structure and reliability has been repeatedly criticised in the psychometric literature. Zakariya (2022), writing specifically about mathematics education research, cautions that a high internal-consistency coefficient does not by itself demonstrated that an instrument is unidimensional, and recommends pairing reliability estimation with confirmatory factor analysis and, where essential tau-equivalence is untenable, using model-based coefficients such as McDonald's omega rather than Cronbach's alpha alone. Dunn et al. (2014) make a parallel argument, showing that omega is less biased than alpha when items vary in their factor loadings, a condition common, and often undetected, in adapted scales whose items were not originally designed as parallel measures. These recommendations directly inform the analytic approach adopted here, in which the factorial structure of the adapted PEOU-AI items is established through CFA before reliability was estimated using omega, rather than assuming the original instrument's properties transfer unchanged to the new referent and population. Read together, the literature establishes three things clearly: PEOU is a theoretically and empirically important construct in AI-acceptance research involving preservice teachers; Nigerian research in this space has grown substantially but has not isolated PEOU-AI as a measurement target in mathematics teacher education specifically; and current psychometric guidance cautions strongly against assuming that an adapted scale retains its original structure and reliability without direct empirical verification. These three observations jointly motivate the present study.

Statement of the Research Problem

Taken together, the reviewed literature suggested the presence of a clearly identifiable and addressable research gap which, to the best of our knowledge at the time of writing, warrants further empirical investigation. While Nigerian AI-acceptance research involving preservice teachers has expanded considerably, it has treated perceived ease of use largely as an embedded predictor within larger structural models, rather than as a construct whose own measurement property,

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dimensionality, item quality, and reliability, in an AI-in-mathematics-learning referent, are independently established. No identified study has adapted Davis's (1989) PEOU subscale specifically to this referent and subjected the adapted items to confirmatory factor analysis and model-based reliability estimation among Nigerian preservice mathematics teachers drawn from structurally different institution types. This leaves teacher educators without a psychometrically examined short-form instrument for tracking ease-of-use perceptions of AI, and without evidence on whether such perceptions are comparable across institutional pathways and gender, both relevant to designing equitable, targeted AI-integration support.

Research Methodology

Research Design

This study adopted a cross-sectional, quantitative survey design because this approach is appropriate for scale adaptation and psychometric validation research. A cross-sectional design collects data at a single time point, allowing efficient evaluation of an adapted instrument's measurement properties without repeated observations (Zakariya, 2022; Castillo-Díaz & Periañez, 2026). This design also enables collection of standardized numerical data suitable for statistical procedures such as exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and reliability testing, which are necessary to establish factorial structure, internal consistency, and validity. Since the primary objective is to assess the adapted scale's suitability rather than to examine changes over time, one-time data collection is methodologically sufficient (Zakariya, 2022; Carcausto Huamaní etal., 2026).

Sampling Technique

A multistage non-probability sampling procedure was used. First, purposive sampling was employed to select three public tertiary institutions in the Federal Capital Territory, Abuja, representing the three institutional types. These institutions were selected because they offer accredited Mathematics Education programmes and represent different institutional types for preparing preservice mathematics teachers. Their inclusion ensured that participants possessed the relevant academic background to provide informed responses on the study variables (Ahmed, 2024; Magnone & Yezierski, 2024). Second, convenience sampling was used to recruit preservice mathematics teachers who were available and willing to participate during data collection. This approach was appropriate because participant access depended on student availability and institutional constraints. Although practical, convenience sampling may introduce selection bias, as participants may differ from non-participants (Ahmed, 2024). The sampling approach was guided by participant eligibility, institutional accessibility, participant availability, and the practical feasibility of data collection. The final sample comprised 221 preservice mathematics teachers across the three institutional types (77 [34.8%] from the open-distance type, 73 [33.0%] from the college of education type, and 71 [32.1%] from the conventional university type). The sample included 112 females (50.7%) and 109 males (49.3%), providing near-balanced gender representation and participation across the three teacher-education pathways. Including participants from different institutional types was relevant because studies have reported variations in AI awareness, utilisation, and adoption in mathematics and STEM education as Olarewaju et al., (2025) identified a gap between AI awareness and utilisation among preservice mathematics teachers, while Awofala et al. (2025) found that perceived usefulness, ease of use, and trust significantly influenced AI adoption among STEM teachers. Accordingly, the selected sample provided an appropriate context for examining preservice mathematics teachers' perceptions (Awofala et al., 2025; Olarewaju et al., 2025).

Ethical Considerations

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The study adhered to established ethical principles for research involving human participants. Institutional permission was obtained before data collection, and participants were informed of the study's purpose, procedures, voluntary nature, and their right to withdraw without penalty. Informed consent was obtained from all participants before participation. Participants' rights, dignity, welfare, and autonomy were protected throughout the study (World Medical Association [WMA], 2024). Participation was voluntary, with no coercion or inducement. No personally identifying information was collected, and responses were used solely for academic purposes and reported in aggregate form. Data were securely stored and accessible only to the researcher to ensure privacy and confidentiality. The study posed minimal risk because it concerned participants' educational experiences, perceptions of AI. The principles of beneficence, nonmaleficence, justice, respect for persons, and confidentiality were maintained throughout the research process (WMA, 2024; Blue Blocks Micro Research Institute, 2026).

Instrument

The Perceived Ease of Use of AI (PEOU-AI) was measured using a six-item questionnaire adapted from the perceived-ease-of-use subscale of the Technology Acceptance Model developed by Davis et al. (1989). The adaptation retained the original structure of the six items while replacing the technology-specific reference with "AI tools for mathematics learning" to suit the context of this study. Table 1 presents a comparison between the original PEOU items and the adapted PEOU-AI scale.

Table 1

Comparison of Original PEOU Items (Davis, 1989) and Adapted PEOU-AI Items

No.	PEOU (Davis, 1989)	Adapted PEOU-AI
1	Learning to operate CHART-MASTER would be easy for me.	Learning to use AI tools for mathematics learning is easy for me.
2	I would find it easy to get CHART-MASTER to do what I want it to do.	I find it easy to get AI tools to do the tasks I want in mathematics.
3	My interaction with CHART-MASTER would be clear and understandable.	My interaction with AI tools for learning mathematics is clear and understandable.
4	I would find CHART-MASTER to be flexible to interact with.	I find AI tools to be flexible to interact with while learning mathematics.
5	It would be easy for me to become skilful at using CHART-MASTER.	It is easy for me to become skilful at using AI tools for learning mathematics.
6	I would find CHART-MASTER easy to use.	I find AI tools easy to use for mathematics learning.

Table 1 presents the primary instrument used for data collection was the Perceived Ease of Use of Artificial Intelligence (PEOU-AI) questionnaire, a six-item structured scale adapted from the Perceived Ease of Use (PEOU) subscale of the Technology Acceptance Model (TAM) developed by Davis et al. (1989). The original PEOU subscale formed part of a 12-item, two-dimensional instrument designed to measure perceived usefulness and perceived ease of use of a technology. For this study, the six original PEOU items were modified by replacing the system-specific reference ("CHART-MASTER") with AI tools for mathematics learning, while retaining the original item structure and meaning. Table 1 presents a comparison between the original PEOU items and the adapted PEOU-AI items. The PEOU-AI questionnaire consisted of two sections. The first section collected demographic information, including respondents' gender and institutional type. The second section comprised six items measuring students' perceived ease of use of AI tools for mathematics learning. Responses were recorded on a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5).

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Validity and Reliability Procedures

The construct validity of the Perceived Ease of Use of Artificial Intelligence (PEOU-AI) scale was assessed using confirmatory factor analysis (CFA). An initial one-factor model comprising six items was specified, with all items loading on a single latent PEOU-AI construct. Model fit was evaluated using the chi-square statistic (x^2), relative chi-square ratio (x^2/df), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Standardized Root Mean Square Residual (SRMR). Model adequacy was assessed using the criteria proposed by Hu and Bentler (1999): $x^2/df < 3.0$, RMSEA ≤ .08, CFI and TLI ≥ .90, and SRMR ≤ .08. Where the hypothesised model failed to achieve acceptable fit, standardized factor loadings and modification indices were examined to identify sources of model misfit. Items with factor loadings below the recommended threshold of .50 were considered for removal, provided that such decisions were theoretically justified and did not compromise the conceptual integrity of the construct. The measurement model was subsequently re-estimated using the retained items. The internal consistency reliability of the final PEOU-AI scale was assessed using McDonald's coefficient omega (ω). Omega was preferred to Cronbach's alpha because it does not require the assumption of essential tau-equivalence and provides a more accurate estimate of reliability when items contribute unequally to the latent construct (Dunn et al., 2014; Zakariya, 2022).

Presentation of Results

Addressing Research Questions One and Two

In order to establish the construct validity of PEOU-AI scale, CFA of the 6-item one-factor PEOU-AI was conducted. The CFA results for the PEOU-AI demonstrated an excellent model fit of the generated data. The global fit statistics of this model are presented in Table 1.

Table 2

The goodness of fit statistics for one-factor PEOU scale

Global fit statistics	Model 1	Model 2
Chi-square		
Estimate (χ^2)	24.291	2.770
Degrees of freedom (df)	9	2
p-value	.0039	.2503
χ^2 / df	2.699	1.385
RMSEA (Root Mean Square Error of Approximation)		
Estimate	.088	.042
90 percent confidence interval	[.047, .131]	[<.001, .147]
Probability RMSEA <= .05	.064	.425
CFI/TLI		
CFI (Comparative Fit Index)	.886	.991
TLI (Tucker-Lewis index)	.811	.972
SRMR (Standardized Root Mean Square Residual)	.064	.026

Model 2 is an improvement on Model 1 by deleting items PEU05 and PEU06.

The presented results in Table 1 show that the initial one-factor model of the Perceived Ease of Use (PEOU) of AI scale (Model 1) did not demonstrate an adequate fit to the data based on the criteria by Hu and Bentler (1999). Although the SRMR (.064) was within the acceptable threshold, the model exhibited a significant chi-square, $x^2(9) = 24.291$, $p = .004$ with an acceptable relative chi-square ($x^2/df = 2.699$) and RMSEA of .088 but a CFI (.886) and TLI (.811) values below the recommended cutoff of .90, indicating poor overall fit. A careful examination of the factor loadings coupled with

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some guide from the modification indices, revealed that item 5 (.389) and item 6 (.354) have low standardised factor loadings. Thus, these two items were deleted from the model yielding Model 2 with a substantial improvement in fit. As presented in Table 1, the Model 2 demonstrates an excellent model fit of the dataset with a non-significant chi-square, $x^2(2) = 2.770$, $p = .2503$ with $x^2/df = 1.385$ (less than 3), RMSEA = .042, CFI = .991, TLI = .972, and SRMR = .026. All fit indices satisfied the Hu and Bentler (1999) criteria for an excellent global fit model, indicating that the revised one-factor four-factor model provides an excellent representation of the observed data and supports the unidimensional structure of the Perceived Usefulness of AI scale.

Addressing Research Question Three

The structural model of this instrument and some local fit statistics are presented in Figure 1. The figure displays the standardised factor loadings of the four retained PEOU-AI items on a single latent factor (PEU), with error variances shown for each observed indicator.

Figure **1**

Standardised estimates of model parameters for the 1-factor PEOU scale

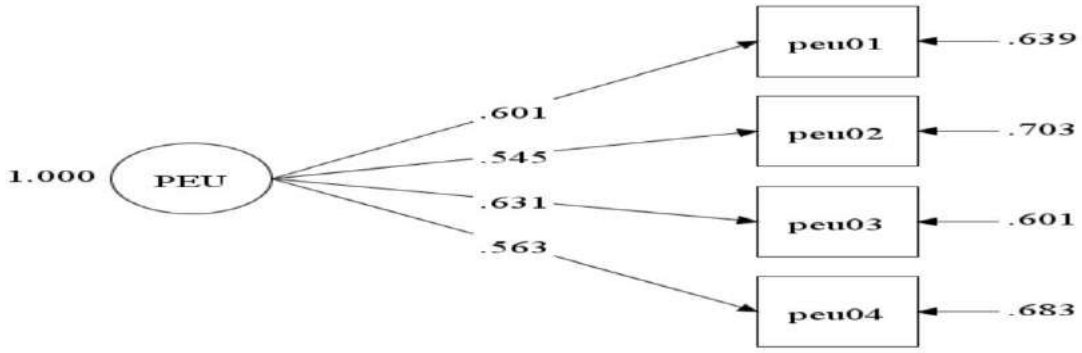


Figure 1 presents the standardised parameter estimates for the one-factor PEOU-AI model comprising four observed items (peu01–peu04). All four items loaded positively and significantly on the latent construct, with standardised factor loadings of .601 (peu01), .545 (peu02), .631 (peu03), and .563 (peu04), all exceeding the .50 threshold recommended for retaining items in a reflective measurement model. The corresponding error variances ranged from .601 to .703, indicating that the latent factor accounted for approximately 30% to 40% of the variance in each item. The uniformly moderate loadings suggest that the four items form a coherent but not redundant unidimensional scale, providing acceptable evidence of convergent validity for the PEOU-AI instrument.

Addressing Research Question Four

The distribution of perceived ease of use of AI (PEOU-AI) scores across institutional types was examined prior to hypothesis testing. Figure 2 presents the mean PEOU-AI scores with error bars, while Tables 3 and 4 report the assumptions and results of the comparative analysis across the three *institutions.*

Figure 2:

Mean perceived ease of use of AI by school type (error bars: ±1 SD)

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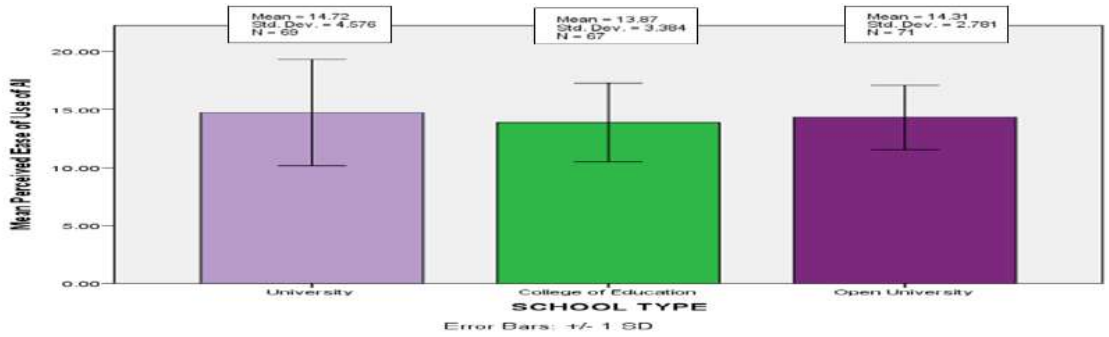


Figure 2 showed that mean PEOU-AI scores were highest among university students (M = 14.72, SD = 4.576, n = 69), followed by open university students (M = 14.31, SD = 2.781, n = 71) and college of education students (M = 13.87, SD = 3.384, n = 67).

Table **3**

Tests of Normality of PEOU-AI Scale across institutional type

	School Type	**Kolmogorov-Smirnov[a]**			**Shapiro-Wilk**		
		Statistic	**df**	**p-value**	**Statistic**	**Df**	**p-value**
Perceive Ease of Use of AI	University	.132	69	.005	.913	69	.000
	College of Education	.184	67	.000	.952	67	.011
	Open University	.132	71	.004	.955	71	.013

a. Lilliefors Significance Correction

The normality tests in Table 3 indicated that PEOU-AI scores deviated significantly from normality in all three institutions (Kolmogorov-Smirnov $p < .05$; Shapiro-Wilk $p < .05$), violating the assumption required for parametric testing. Consequently, the non-parametric Kruskal-Wallis test was employed. As shown in Table 4,

Table **4**

Kruskal-Wallis test of mean difference in PEOU across institutions

School Type	**N**	**Mean Rank**	**Chi-Square**	**df**	**p-value**
University	69	114.65			
College of Education	67	95.67	3.637	2	.162
Open University	71	101.51			

Table 4, revealed that the test had no statistically significant difference in PEOU-AI scores across the three institutional types, $x^2(2) = 3.637$, $p = .162$. The mean ranks were 114.65 for university students, 95.67 for college of education students, and 101.51 for open university students. These findings indicated that preservice mathematics teachers' perceived ease of use of AI did not differ significantly by institutional affiliation.

Addressing Research Question Five

The distribution of perceived ease of use of AI (PEOU-AI) scores across gender was examined prior to hypothesis testing. Figure 3 presents the mean PEOU-AI scores with error bars, while Tables 4 and 5 report the assumptions and results of the comparative analysis between male and female participants

Figure 3

Mean perceived ease of use of AI by gender (error bars: ±1 SD)

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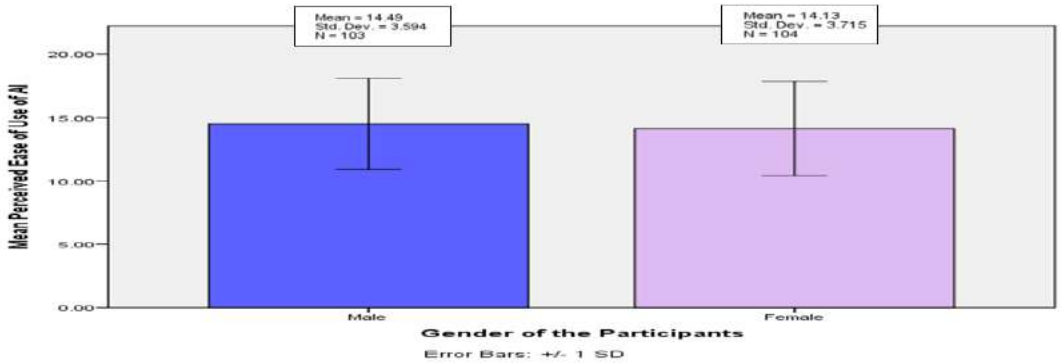


Figure 3 showed that male participants reported slightly higher mean PEOU-AI scores (M = 14.49, SD = 3.594, n = 103) than female participants (M = 14.13, SD = 3.715, n = 104).

Table **5**

Tests of Normality of PEOU-AI Scale across institutional type

	Gender of the Participants	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	p-value	Statistic	df	p-value
Perceived Ease of Use of AI	Male	.106	103	.006	.965	103	.008
	Female	.151	104	<.001	.944	104	<.001

a. Lilliefors Significance Correction

The normality tests in Table 5 indicated that PEOU-AI scores deviated significantly from normality for both male (Kolmogorov-Smirnov p = .006; Shapiro-Wilk p = .008) and female (Kolmogorov-Smirnov p < .001; Shapiro-Wilk p < .001) participants, violating the assumption required for parametric testing. Consequently, the non-parametric Mann-Whitney U test was employed. As shown in Table 6,

Table **6**

Mann-Whitney test of mean difference in PEOU across gender

School Type	N	Mean Rank	Sum of Rank	U – value	z-value	p-value
Male	103	106.36	10955.00	5113.00	-.567	.571
Female	104	101.66	10573.00			

Table 6, revealed that the test had no statistically significant difference in PEOU-AI scores between male and female participants, U = 35113.00, z = −.567, p = .571. The mean ranks were 114.65 for males and 101.51 for females. These findings indicated that preservice mathematics teachers' perceived ease of use of AI did not differ significantly by gender.

Discussion of Findings

The findings provide evidence that the adapted Perceived Ease of Use of Artificial Intelligence (PEOU-AI) scale is a valid measure for assessing preservice mathematics teachers' perceptions of AI ease of use. The initial six-item one-factor model did not meet all recommended model-fit criteria, with the Comparative Fit Index (CFI = .886) and Tucker-Lewis Index (TLI = .811) falling below the recommended .90 threshold (Hu & Bentler, 1999). Examination of the factor loadings showed that two items, “becoming skillful at using AI” and “AI is easy to use”, loaded weakly on the construct, indicating that they did not adequately measure perceived ease of use in this context. After these items were removed, the four-item model achieved excellent fit and satisfied all recommended criteria. The results therefore answered the first three research questions. First, the retained four items measured a single underlying construct, confirming the unidimensional nature of the PEOU-

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AI scale. Second, the retained items demonstrated strong relationships with the construct, indicating that they were appropriate indicators of perceived ease of use. Third, the final model showed excellent fit, suggesting that it accurately represented the observed data. These findings support the view that measurement instruments adapted from existing theories should be empirically validated before use in new contexts, rather than assuming that the original scale will function equally well with a different technology or population (Zakariya, 2022; Bernardi et al., 2025).

The scale also demonstrated acceptable internal consistency reliability (ω = .723). This value indicated that the four items consistently measured the same construct and are suitable for research purposes. Although the reliability estimate meets accepted standards, it also suggests room for improvement through the development of additional AI-specific items that may strengthen the scale in future studies (Dunn et al., 2014; Zakariya, 2022). The findings further revealed no significant differences in perceived ease of use of AI across institution types. Preservice mathematics teachers from universities, colleges of education, and the open university reported similar levels of perceived ease of use. This suggests that AI ease-of-use beliefs are relatively consistent across the different teacher education pathways represented in the study. One possible explanation is the increasing accessibility of AI tools through mobile technologies and digital platforms, which may provide students with similar opportunities for exposure regardless of institutional context (Ayanwale et al., 2024). Similarly, no significant gender differences were found in perceived ease of use of AI. Male and female preservice mathematics teachers reported comparable perceptions regarding the ease of using AI tools. This finding aligns with previous studies that have shown limited or no gender differences in core technology acceptance beliefs, particularly perceived ease of use (Zhang et al., 2023). The result suggested that gender may not be a major factor influencing initial perceptions of AI usability among preservice mathematics teachers. Finally, the study demonstrated that the four-item PEOU-AI scale is a valid and reliable instrument for measuring perceived ease of use of AI among preservice mathematics teachers. The absence of significant differences across institution types and gender further suggests that perceptions of AI ease of use are broadly shared within the study population. These findings provide encouraging evidence that AI-related learning technologies may be accepted similarly across different preservice teacher groups within the FCT, Abuja.

Implications of the study

The validated four-item Perceived Ease of Use of Artificial Intelligence (PEOU-AI) scale provides mathematics teacher educators with a short and reliable instrument for assessing preservice teachers' perceptions of the ease of using AI tools in mathematics education. Because the scale demonstrated good model fit, unidimensionality, and acceptable reliability, it can be used with greater confidence than unvalidated adaptations of existing Technology Acceptance Model (TAM) measures. For teacher education institutions and policymakers, the absence of significant differences across institution types and gender suggested that AI-related training and support programmes can initially be designed for all preservice mathematics teachers rather than targeted at specific groups. Efforts should therefore focus on increasing exposure to and competence in the use of AI tools for mathematics teaching and learning. For researchers, the findings highlight the importance of validating adapted measurement instruments before use. Even widely accepted scales should be subjected to confirmatory factor analysis and reliability testing when applied to new contexts or populations. However, these implications are limited to the population studied and should not be generalized beyond preservice mathematics teachers in the FCT, Abuja, without further validation.

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Limitations of the Study

Some limitations should be considered when interpreting the findings. The study employed a cross-sectional design, which captured participants' perceptions at only one point in time and could not examine changes in perceptions with increased exposure to AI tools. The data were self-reported, making the results susceptible to social desirability bias and common-method bias. Finally, the participants were drawn from only three higher institutions in the FCT, Abuja. Therefore, the findings should not be generalized to preservice teachers in other regions of Nigeria or to in-service teachers without additional validation studies.

Conclusion

This study adapted and validated a Perceived Ease of Use of Artificial Intelligence (PEOU-AI) scale among preservice mathematics teachers from three higher institutions in the FCT, Abuja. Following the removal of two poorly performing items, a four-item, one-factor scale demonstrated excellent model fit and acceptable internal consistency, supporting its suitability for measuring perceptions of AI ease of use in mathematics education. The findings further showed that perceptions of AI ease of use did not differ significantly across institution types or gender groups. The study therefore provides a brief and psychometrically supported instrument that can be used in future research on AI adoption among preservice mathematics teachers.

Recommendations for Future Research

1. Future studies should validate the four-item PEOU-AI scale using larger and more geographically diverse samples of preservice mathematics teachers across Nigeria to determine whether the factor structure and model fit remain stable.
2. Researchers should also examine the scale within a complete Technology Acceptance Model framework by investigating its relationships with perceived usefulness, attitude toward AI, and behavioural intention to use AI.
3. measurement invariance should be tested across gender and institution types before making strong group comparisons.
4. Longitudinal studies are recommended to examine how perceptions of AI ease of use change as preservice teachers gain more experience and training in the use of AI tools for mathematics instruction.

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Qualitative Study on Strengthening Universal Science, Technology, Engineering and Mathematics Education: An Exploration of SUSTAIN-STEM Model

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Abstract

Despite global commitments to the 2030 Agenda, STEM education remains largely disconnected from pressing sustainability challenges such as climate change, energy, and waste. This conceptual paper argues that integrating sustainability is critical to strengthening universal STEM education that is equitable, relevant, and impact-driven. Drawing on the UNESCO ESD framework and Systems Thinking, the paper proposes the SUSTAIN-STEM Model: a 7-dimension framework comprising Systems Thinking, Use of Local Context, Sustainable Innovation, Teacher Capacity, Assessment for Impact, Inclusivity, and Networking. The model repositions STEM from mere content delivery to solving real-world sustainability problems through green pedagogy, community-based projects, and inclusive practices. Implications are discussed for curriculum redesign, teacher education in Colleges of Education, Policy Support, and low-cost green labs. Key challenges including resource constraints and exam-focused cultures are addressed with strategies such as partnerships and open educational resources. The paper concludes that Universal STEM education must evolve into STEM for sustainable development to achieve SDG 4 and SDG 13.

Keywords: Sustainability, STEM Education, ESD, Universal Access, Green Pedagogy.

Introduction

Science, Technology, Engineering and Mathematics (STEM) has to do with explaining natural phenomena and the technology and innovation needed to solve real world problems. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2017; UNESCO, 2020) STEM educational is an interdisciplinary approach to teaching that fosters critical thinking, problem solving and innovation by integrating science, technology, engineering and mathematics. STEM education is the bedrock of development and is crucial to producing individuals who possess the knowledge and skills for collaboration and problem solving through innovative thinking. According to Ayua et al. (2023a) education is functional to the extent that it fits meaningfully into

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the society. Thus, STEM education in the 21st century must be functional by fostering sustainable development. Sustainability is the central theme of the United Nations 2030 agenda. it has become the global watch-word in virtually all areas of human endeavours especially in technology, innovation and development. Sustainability seeks to balance environmental, social and economic resources so that present needs are met without undermining the ability of future generations to meet their needs. It is in light of this that the United Nations (2015) advocated for education that promotes sustainable development practices and sustainable lifestyle in line with Sustainable Development Goal 4. Education is the heart of global culture and the instrument for social change and development. Therefore, integrating environmental, social and economic sustainability consciousness will deliver sustainable development and innovations. Sustainable Development is the viable ability of a nation to improve the lives of her citizens within the context of a growing economy with emphasis on the good of the society as a whole (Ayua et al., 2022). This implies that development that is sustainable is one that improves the lively-hood of present citizens without compromising the lively-hood of future generations. The need for sustainable development has necessitated a paradigm shift in STEM education in the 21st century to one that emphasizes creativity, critical thinking and practical problem solving. (Ayua et al., 2026). This is to facilitate global technological and scientific advancements and innovations that preserve the integrity of the environment. The global landscape is facing prevailing challenges such as global economic crisis, climate change, poverty and insecurity which threaten sustainable development and human survival (Ayua & Gamat, 2018). As a remedy for these challenges Ayua et al., (2022) prescribes education for sustainable development. Education that promotes sustainable development is sound, functional, result-oriented, problem-solving, societal need-meeting, creativity tailored and that enhances the global sustainability agenda (Ayua, 2019; Okonkwo et al., 2024, Olaleye et al., 2023). The fight for sustainability is a global endeavour therefore education for sustainable development must be universally accessible. Similarly, education for sustainable development is one that adopts a green-pedagogical approach. Green pedagogy is a sustainability-oriented pedagogical approach that integrates ecological, social and economic dimensions into teaching and learning with the aim of developing learners' sustainability competencies and capacity for environmental responsibility (Fox & Wogowitsch, 2021).

Statement of the Problem

STEM is traditionally taught as a body of knowledge and in isolation from sustainability/real-world challenges like climate change, energy and water conservation. This isolation limits students' ability in connecting STEM Knowledge to solving real world problems. Researchers have lamented on this approach, advocating for a sustainability-oriented approach that prepares learners not only with STEM knowledge but also with relevant problem-solving skills required to address the pressing global need for sustainability (Tarlochan et al., 2025; Ayua et al., 2026a). Despite these perspectives, sustainability issues are not yet sufficiently integrated into STEM teaching and learning. Since sustainability challenges are interconnected, there is a need to strengthen STEM education by integrating sustainability principles and real-world problems into teaching and learning. Such integration can promote interdisciplinary perspective, critical thinking, creativity, innovation and problem-solving skills, while preparing learners to contribute meaningfully to the achievement of the Sustainable Development Goals.

Purpose of the Study

The purpose of this conceptual study is to examine how the integration of sustainability principles can strengthen universal Science, Technology, Engineering and Mathematics (STEM) education. Specifically, the study seeks to conceptualize a framework that connects STEM knowledge,

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sustainability challenges and real-world problem-solving in order to make STEM education more relevant, interdisciplinary, inclusive and responsive to contemporary global and local challenges.

Significance of the Study

This paper aims to provide a framework for policymakers to develop/strengthen policies that connect STEM education with sustainability and real-world societal challenges. The paper will be significant for curriculum development by proposing an integration of sustainability in STEM education. Similarly, this paper will be relevant in actualizing Sustainable Development Goals 4 (Quality Education), which seeks to ensure that learners develop the knowledge and skills required to promote sustainable development and Sustainable Development Goals 13 (climate Action) that calls for improving education, awareness and capacity building for addressing climate change.

Scope of the Study

This conceptual paper recognizes that sustainability challenges such as climate change, energy and waste management are not limited to particular countries or regions but are global issues. This paper draws from a global perspective with examples from developing contexts.

Conceptual Clarifications.

Concepts of universal STEM education, sustainability and Education for Sustainable Development (ESD), and the Interconnection are hereby clarified.

Universal STEM education: Universal STEM education is one that is accessible, equitable, relevant and inclusive irrespective of geography, gender, race or physical ability. STEM education is universally relevant because it develops in learners the scientific, technological, engineering and mathematical knowledge necessary to address global challenges, promote innovation and contribute to sustainable development. In line with SGD 4, universal STEM education ensures that technical and critical-thinking skills are treated as a basic right for all learners, and not just a select few. It is in light of this that Kelley and Knowles (2016) links Universal STEM education to the environmental, social and economic challenges of the 21st century.

Defining Sustainability and Education for Sustainable Development:

Sustainability simply means meeting our present needs without harming the ability of future generations to meet their own needs. Sustainability relies on three main parts, often called people, planet, and profit. Harvey et al., (2022) found that contemporary definitions of sustainability commonly emphasize three dimensions; environmental, social, and economic as well as inter-generational responsibility and ethical considerations. Accordingly, Drury et al. (2023) provide a broader definition, viewing sustainability as an ethical responsibility to minimize present and future negative impacts on people, other living organisms, and the planet while maximizing positive impacts. Education for Sustainable Development (ESD) is an educational approach that imparts in the learners, the knowledge, skills, values, and attitudes needed to make responsible choices for the environment, the economy, and society. It is a vital part of quality education and a key driver for achieving the UN Sustainable Development Goals (SDGs). ESD focuses on three main pillars of learning: cognitive, socio-emotional and behavioural. The cognitive dimension improves how we think, understand complex systems, and build knowledge about global challenges. Socio-emotional involves building empathy, solidarity, social skills, and emotional intelligence. Behavioural, Encourages actions, personal responsibility, and positive practical changes in daily life. In this regard, Ayua et al. (2026a) emphasized the importance of developing learners' creative minds and practical abilities through solution-based STEM education as a means of preparing them to address real-world challenges and contribute to sustainable development.

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The interconnection:

Universal STEM education is central to addressing sustainability challenges because science provides the knowledge required to understand natural and human systems, technology provides tools for developing solutions, engineering supports the design and implementation of practical solutions, while mathematics provides the basis for measurement, modelling, data analysis and evidence-based decision-making. In the Nigerian context, STEM education has been identified as important for addressing societal challenges, including environmental problems and climate change (Abiodun et al., 2025). Furthermore, Olayeye et al. (2023) found that inclusive STEM education in Nigerian schools has implications for students' awareness of sustainable development, while also highlighting the importance of ensuring that learners from different backgrounds have equal opportunities to participate in STEM education. This suggests that strengthening STEM for sustainability should not focus only on scientific and technological knowledge but should also promote equitable access and participation.

Literature Review/Theoretical Framework

Global Status of STEM education and gaps in sustainability integration, Sustainability challenges requiring STEM solutions Models of Integrating sustainability into STEM, and theoretical Bases are reviewed.

Global Status of STEM education and gaps in sustainability integration:

Globally, STEM education is recognized as a cornerstone of progress and competitiveness. Developed nations like the United States, Germany, and Japan have long invested in STEM programs to maintain their technological edge. These countries are implementing comprehensive STEM curricula, promoting STEM careers, and investing in research and development to ensure sustainable growth. In Africa UNESCO recognizes STEM as an important driver of innovation and sustainable development and emphasizes the need to strengthen STEM capacity. In the Nigerian context, Aina (2022) notes that STEM education has contributed to development in sectors such as health, agriculture and telecommunications, although its effectiveness is constrained by several systemic challenges. Despite the increasing recognition of STEM education, its implementation remains uneven, particularly in developing countries. Nigerian evidence indicates that inadequate funding, poor-quality teaching, limited research capacity, inadequate infrastructure and shortages of qualified teachers continue to affect STEM education. According to Ayua et al. (2026b) inadequate infrastructure, outdated curricula and shortages of qualified educators as major barriers to achieving high-quality education in Nigeria. Connecting STEM disciplines with sustainability can make learning more meaningful while preparing learners to address environmental and developmental challenges. However, a significant gap remains in the integration of sustainability into STEM education. Although environmental and sustainability issues are increasingly recognized within education, they are not always systematically connected to STEM concepts, teaching methods and learning activities. Tarlochan et al. (2025) emphasize the need to incorporate sustainability issues into educational curricula, strengthen teacher training and use technology to improve educational outcomes in Nigeria. Their argument reinforces the need for an educational system in which sustainability is not treated as an isolated topic but is incorporated into the curriculum and teaching process. The sustainability gap can therefore be understood at several levels: curriculum, pedagogy, teacher preparation, infrastructure and inclusion. Strengthening STEM education through sustainability provides an opportunity to address both educational and societal challenges. Rather than teaching science, technology, engineering and mathematics as isolated areas of knowledge, STEM can be organized around authentic sustainability problems.

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Sustainability challenges requiring STEM solutions:

Sustainability challenges are problems that threaten the ability of present and future generations to meet their needs while maintaining environmental, economic, and social well-being. Examples of sustainability challenges include: climate change, environmental pollution, biodiversity loss, deforestation, waste management among others. Sustainability challenges require STEM solutions because the environment depend heavily on scientific knowledge, technological innovation, engineering design and Mathematical analysis. Climate change requires scientific understanding, technological innovation and engineering approaches to reduce greenhouse-gas emissions and strengthen adaptation and resilience. Similarly, the transition to clean energy depends on advances in renewable-energy technologies, energy efficiency and energy-storage systems. Water-related challenges, including pollution, scarcity and flooding, require scientific knowledge and engineering solutions for water treatment, conservation and effective management. The circular economy also depends on STEM innovations in sustainable materials, recycling, waste management and resource efficiency. In Nigeria, STEM education has been identified as having the potential to address societal challenges, including climate change and natural-resource depletion (Federal Ministry of Education [FME], 2019).

Models of integrating sustainability into STEM:

The models for integrating sustainability into Science, Technology, Engineering and Mathematics (STEM) are stated as follows.

1. **Green STEM:** Green STEM refers to the integration of environmental sustainability principles into Science, Technology, Engineering and Mathematics education. It encourages learners to use STEM knowledge to understand environmental problems and develop practical solutions to challenges such as climate change, renewable energy, pollution, waste management and water scarcity. This approach shifts STEM learning from merely acquiring disciplinary knowledge toward using that knowledge to address real-world sustainability problems. Ogundare and Ibrahim (2026), argued that strengthening STEM education from a sustainability perspective can contribute to preparing learners to respond to contemporary societal and developmental challenges
2. **Eco-pedagogy:** Eco-pedagogy is an educational approach that develops learners' awareness of the relationship between humans, society and the natural environment. Rather than teaching environmental issues as an isolated topic, it encourages students to critically examine how human activities affect ecosystems and how communities can adopt more sustainable practices. Eco=pedagogy as a dimension of the SUSTAIN-STEM model seeks to leverage on the scientific attitudes, to develop in learners' environmental consciousness and an ethical responsibility towards ensuring sustainable use of the environment (Ayua & Kwagh, 2026)
3. **Project-Based Learning:** Project-Based Learning provides a practical mechanism for integrating sustainability into STEM. In PBL, learners work on authentic problems over a period of time and apply knowledge from different STEM disciplines to develop a solution or product. Bolstad et al. (2021) and Bolstad et al. (2023) note that project-based learning provides a suitable arena for integrating sustainability. Similarly project-based learning has been linked to learners' development of problem-solving and critical thinking skills (Bahar & Aksut, 2020; Nwosu et al., 2023)

Theoretical Basis: The theoretical footing of this study on strengthening universal STEM education via sustainability is fastened on three complementary frameworks. First, the UNESCO Education for

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Sustainable Development (ESD) for 2030 framework (UNESCO, 2020), advocated by UNESCO as an evolution of the UN Decade of ESD (2005-2014), postulates that education must advance knowledge, skills, values, attitudes and behaviours for sustainable development. It assumes that learning should be transformative and action-oriented to allow learners to address present-day sustainability challenges. Its implication is that it provides the philosophical validation for reorienting STEM education from sheer disciplinary knowledge transmission to a vehicle for sustainable advancement and the achievement of the SDGs. Second, Systems Thinking Theory, founded on Bertalanffy (1968) and popularized by Senge (1990), holds that multifaceted problems must be understood through the interactions and mutuality among system components rather than in isolation. It is a holistic approach for examining complex difficulties and systems that focus on the interactions among system components and the patterns that emerge from those interactions (York et al., 2019). It assumes that sustainability problems such as climate change, energy insecurity and water scarcity are interrelated systems. Its implication is that it offers the conceptual lens for strengthening STEM education, needing that STEM be taught as an interdisciplinary enterprise where scientific, technological, environmental, social and economic systems relate. Third, Constructivist Learning Theory propounded by Piaget (1936) and Vygotsky (1978) asserts that learners actively construct knowledge from experience. It assumes that meaningful learning occurs through active engagement with real-world problems. Its implication is that it provides the pedagogical basis for strengthening STEM education, suggesting that sustainability-based problem-solving enables learners to meaningfully construct STEM knowledge and competencies essential for sustainable development.

The SUSTAIN-STEM Model

The rationale of the model, model dimensions, and the model's implication on universal STEM education are discussed.

Rationale: STEM Education traditionally emphasis on the acquisition of disciplinary knowledge, concepts, principles and procedural skills in science, technology, engineering and mathematics. Although these foundational competencies remain essential, an exclusive emphasis on content acquisition may limit opportunities for learners to apply STEM knowledge to complex problems beyond the classroom. Moving STEM from content to impact involves creating learning experiences in which learners apply scientific and mathematical knowledge, technological tools and engineering processes to authentic problems. Rather than merely learning about concepts such as energy, water, climate or waste, Impact-driven STEM education encourages students to investigate these issues, analyse evidence, develop possible solutions, test their ideas and evaluate their environmental and social implications. Such an approach transforms learners from passive recipients of STEM knowledge into active problem-solvers, designers and innovators.

Dimensions of the SUSTAIN-STEM Model

The seven dimensions of the model are represented by "SUSTAIN", which includes: S (Systems thinking), U (Use of local context), S (Sustainable innovation), T (Teacher capacity), A (Assessment for impact), I (Inclusivity), and N (Networking). These are stated as follows.

S - Systems thinking: Sees sustainability challenges are being complex and interconnected rather than isolated problems. Issues such as climate change, water, energy and waste involve interactions among environmental, social, technological and economic systems. With the SUSTAIN-STEM Model, systems thinking involves presenting learners with authentic sustainability problems and encouraging them to identify the different components of the problem, examine the relationships among these components, and consider the possible solutions.

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U – Use of local context: Stresses the need to connect STEM education with learners' immediate environment, community experiences, local resources, and indigenous knowledge. Rather than presenting STEM concepts as abstract ideas that exist only in textbooks, learners can be encouraged to investigate sustainability challenges within their own communities and apply STEM knowledge to develop practical solutions. Research has linked indigenous science teaching to development of learners' cognitive reasoning, innovative thinking and critical thinking skills (Ayua et a., 2023c; Adam et al., 2024; Ayua et al., 2025).

S – Sustainable innovation: Encourages the use of STEM knowledge, creativity, design thinking, and engineering processes to develop innovative solutions to sustainability challenges. Rather than presenting STEM as a body of theoretical knowledge, this dimension encourages learners to apply what they learn to identify problems, generate ideas, design solutions, test prototypes, evaluate outcomes, and improve their designs. sustainable innovation positions learners not only as consumers of scientific and technological knowledge but also as potential innovators and problem-solvers. Design thinking provides an appropriate approach for promoting sustainable innovation because it encourages learners to understand the needs of people and communities before developing solutions. Incorporating green technology and engineering challenges into STEM education, students can develop the capacity to design solutions with less negative impacts on the environment. Innovative STEM teaching fosters and innovative skills in learners (Ayua et al., 2023b)

T – Teacher capacity: Recognizes that the successful integration of sustainability into STEM education depends largely on teachers' knowledge, skills, attitudes, and confidence. Teachers require adequate preparation to connect STEM concepts with Education for Sustainable Development (ESD), facilitate interdisciplinary learning, and engage students in solving authentic sustainability problems. Teacher capacity development should equip educators with practical skills for designing learner-centred and inquiry-based activities. Well-prepared teachers are better positioned to transform STEM classrooms into spaces where learners acquire knowledge, develop practical skills, and apply STEM to address real-world sustainability challenges.

A – Assessment for impact: Highlights the need to assess not only students' acquisition of STEM knowledge but also their ability to apply that knowledge to address real-world sustainability challenges. Traditional examinations often focus on students' ability to recall concepts, procedures, and facts, whereas sustainability-oriented STEM education requires learners to demonstrate how they can use knowledge to investigate problems, develop solutions, and evaluate their impacts. Assessment within the SUSTAIN-STEM Model should therefore include approaches such as project assessment, practical tasks, design challenges, presentations, problem-solving activities, and community-based projects. These approaches can provide evidence of learners' creativity, critical thinking, collaboration, innovation, systems thinking, and ability to apply STEM concepts to sustainability problems.

I – Inclusivity: Heartens equitable access to quality STEM and sustainability education for all learners irrespective of gender, location, socioeconomic background, or disabilities. Integrating inclusivity into sustainability-oriented STEM education requires deliberate efforts to remove barriers that limit learners' participation and achievement. Gender stereotypes, inadequate learning facilities, limited access to technology, poverty and geographical location can influence learners' opportunities to engage meaningfully in STEM. Inclusivity in SUSTAIN-STEM Model therefore promotes learning environments in which every learner is encouraged to participate, experiment, innovate, and contribute ideas to sustainability challenges.

N – Networking: Networking dimension emphasizes building partnerships and collaborative relationships among schools, universities, governments, industries, research institutions,

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communities, NGOs, and international organizations to strengthen STEM education for sustainability. Global networking provides opportunities for sharing knowledge, technologies, teaching resources, research findings, and innovative practices across different contexts.

Thus, the SUSTAIN-STEM Model strengthens universal STEM education by promoting an approach to STEM teaching and learning that is inclusive, relevant, interdisciplinary, and connected to real-world sustainability challenges. Rather than treating Science, Technology, Engineering, and Mathematics as isolated subjects, the model connects STEM knowledge with issues such as climate change, energy, water, waste etc. This makes STEM education meaningful and encourages learners to apply their knowledge to problems within their communities and the wider world.

Implications for Curriculum, Policy and Practice

Redesigning STEM curricula, green labs, policy support, and the role of Colleges of Education are hereby discussed.

Redesigning STEM curriculum to embed SDGs and sustainability competencies: A sustainability-oriented STEM curriculum should move beyond content acquisition to emphasize the application of knowledge to problems. Curriculum redesign should explicitly connect STEM learning outcomes with the Sustainable Development Goals (SDGs).

Green laboratory, makerspaces, and low-cost sustainable experiments: Green laboratory practices should be embedded into science curricula to promote efficient use of resources, Government and relevant education agencies should develop guidelines and funding mechanisms for establishing green laboratories and school makerspaces. STEM policies should recognize that effective practical learning does not always require expensive equipment and should encourage the development and use of locally produced and low-cost teaching resources.

Policy support: Government and educational stakeholders should provide adequate and sustainable funding for STEM facilities, green laboratories, makerspaces, teaching materials, digital resources, and community-based STEM projects. Policies should support continuous professional development that equips teachers with knowledge and skills in Education for Sustainable Development (ESD). Assessment policies should move beyond an exclusive emphasis on examinations and recall of STEM content into assessment approaches that capture learners' ability to apply knowledge and solve problems.

Teacher training institutions' role: To produce sustainability-literate STEM teachers, the institutions should mainstream Education for Sustainable Development (ESD), climate education, and the Sustainable Development Goals (SDGs) into their STEM teacher education curricula. This entails equipping potential teachers with capabilities in systems thinking, inquiry-based learning, project-based learning, problem-solving, design thinking, and interdisciplinary pedagogies needed for sustainability-oriented STEM teaching. Also, teacher training institutions should create green laboratories, makerspaces, and sustainability-focused hands-on projects where teacher trainees can design and improvise low-cost, environmentally welcoming STEM teaching-learning solutions utilizing locally obtainable materials, and thus consolidating universal STEM education via sustainability.

Challenges and Strategies for Implementation

The following implementation challenges and strategies are advanced.

Resource Constraints, Lack of Awareness, and Exam-Focused Culture: Inadequate funding, poorly equipped laboratories, limited access to digital technologies, unreliable electricity, and shortages of instructional materials can hinder the implementation of practical STEM and sustainability activities. Limited understanding of the connection between STEM education and

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sustainability among teachers, school leaders, and other stakeholders may affect effective implementation. An examination-driven culture may also encourage memorization rather than creativity, critical thinking, innovation, and problem-solving.

Strategies for Implementation:

Partnerships, Open Educational Resources, Community Projects and International Collaboration.

1. Partnerships among governments, schools (at all levels), industries, non-governmental organizations (NGOs), and local communities can provide the resources and expertise needed to strengthen sustainability-oriented STEM education.
2. The use of Open Educational Resources can reduce the cost of accessing quality STEM and sustainability learning materials. Teachers and learners can access freely available textbooks, simulations, videos, and practical activities through digital platforms.
3. Connecting STEM education with community sustainability challenges can make learning more meaningful and encourage students to apply knowledge beyond the classroom.
4. Schools can organize projects around locally relevant issues such as waste disposal, water conservation, energy use, food and environmental pollution. Students may collect data, identify problems, design possible solutions, test their ideas, and evaluate their impact.
5. Community-based projects promote problem-solving, creativity, critical thinking, collaboration, and systems thinking while allowing learners to see STEM as a tool for addressing real-life challenges.
6. International collaboration can strengthen the exchange of knowledge, innovations, teaching resources. Schools, researchers, and educational organizations can collaborate across countries through joint research, virtual learning programmes, teacher networks, student projects, and professional development initiatives. Such collaboration exposes educators and learners to diverse approaches to sustainability while still allowing them to adapt these approaches to local needs.

Conclusion

Summary, Call to Action, and Future research directions are discussed.

Summary: STEM education cannot be considered truly universal if it remains disconnected from the social, economic, and environmental challenges that affect learners and their communities. Universal STEM education should therefore move beyond the transmission of scientific and technical knowledge to emphasize the application of STEM in addressing real-world.

Call to Action: There is a need to move from STEM education to STEM for Sustainable Development by integrating sustainability into STEM teaching and learning. Schools, educators, policymakers, communities and international partners must work together to ensure that STEM knowledge is applied to real-world challenges. This action will help develop learners who are not only knowledgeable in STEM but are also innovative, responsible, and capable of creating solutions that contribute to the Sustainable Development Goals (SDGs).

Future Research Directions: Future research should test the effectiveness of the SUSTAIN-STEM Model in improving students' STEM competencies and ability to develop solutions to real-world sustainability challenges.

Recommendations

1. Governments should strengthen policy and funding for STEM education by supporting sustainability-focused programmes.
2. Teacher training institutions should produce sustainability-literate STEM teachers through integrating ESD and SDGs into curricula, building capabilities in systems and design thinking, and founding green laboratories and makerspaces for low-cost home-grown solutions.

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3. Non-teacher training schools should fortify universal STEM education by means of integrating sustainability and the SDGs into STEM curricula by real-world, and problem-based learning.
4. Assessment systems should be reformed to measure not only students' content knowledge but also their creativity, critical thinking, collaboration, innovation, and ability to apply STEM knowledge to sustainability problems

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Assessment of Lifelong Learning Needs in The Later Life of Older Adults Enrolled in Continuing Education Programmes: A Comparative Study of Southern and Northern Nigeria

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Abstract

The number of the ageing population is increasing daily and has significantly impacted socio-economic status in both developed and developing countries. This calls for greater attention from the government and experts. Therefore, this study provides an X-ray of lifelong learning needs in the later years of older adults. The following research questions were answered: (i) What is the regional policy of lifelong learning in the later years of older adults in Nigeria? (ii) What factors motivate older adults' participation in continuing education programmes for learning in the later years? (iii) What are the challenges and prospects of lifelong learning needs in the later years of older adults? The study adopted a cross-sectional survey. The population of the study consisted of male and female older learners who are within the age range of 30-50 years. A total of thirty older learners were selected for the interview (qualitative data), and three (3) experts were selected for the interview in every programmes area namely: 1 course facilitator, 1 programme organiser, and 1 administrator, respectively. The purposive and snowball sampling techniques were used in selecting the older learners, while, the purposive and convenience sampling techniques were used in selecting three (3) experts. The study strictly adhered to ethical considerations guiding research conduct. The study found that factors motivating older adults' participation include: personal growth, career attainment, and health and well-being. This study recommends that the policy makers on education should design curriculum content on educational gerontology that will meet the learning needs of older adults in Nigeria.

Keywords: Lifelong learning needs, later life**,** older adults and continuing education

Introduction

Learning has been found to have a positive impact on behavioural change in the recipients. This is because learning is an indispensable part of human life. In this regard, lifelong learning is considered a prerequisite for imparting knowledge and skills to learners at any given time. Formosa (2021) argued that lifelong learning constitutes one of the pillars of active ageing on the basis that learning reinforces wellbeing and enables older people to stay healthy and engaged in society. Andreev (2022) reported that lifelong learning is a form of self-initiated education that is focused on personal development for young and older adult learners. The author further noted that lifelong learning enhances skill development, which includes interpersonal skills, creativity, problem-solving, critical thinking, leadership, reflection, and adaptability. Lifelong learning is an area of priority and interest for the European Union and other developed countries. Yang (2015) observed that the development of lifelong learning policies in many UNESCO Member States has shown a growing demand by adults and young people for the knowledge, skills and competences acquired in the course of their life experiences to be made visible, evaluated and accredited within different contexts (work, education, family life, community and society). Learning in later years has taken centre stage as an area of priority and research interest across the regions of the world. The European Union's Green Paper on Ageing (2021) stresses the importance of addressing educational and lifelong learning needs of older adults at both national and regional levels. The policy underscores the importance of learning as a lifelong process, and older adults should be provided with opportunities to reskill and upskill in line with changing personal and societal demands (European Commission, 2021). In the same vein,

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Formosa (2012) noted that the European Union's policy on learning in later life has been subject to critical analysis. The author further noted that the EU recognizes the importance of lifelong learning for older adults; its approach has been criticized for being economically biased and ageist. The EU's vision for older adult education is primarily focused on employability and economic growth, neglecting other important aspects of late-life learning.

Furthermore, learning in later years is essential to meaningful living because learning is a continuing process throughout the lifetime. United Nations Department of Economic and Social Affairs (2019) reported that the fast-growing number of older adults during the last few decades across the globe has impacted significantly on the economic and social functions of societies in both industrialized and developing regions. Therefore, the learning needs of older adult and their well-being have become a global concern that calls for the greater attention of all and sundry. Learning in the later life of older adults has become a major topic of debate and public discourse in both developed and developing nations. In this wise, learning in later years has been interpreted in different ways. Schmidt-Hertha, Formosa, and Fragoso (2019) opined that learning in later life has entrenched itself as an integral part of adult education research, focusing on the diverse provision of late-life learning, the motivations and interests of older learners, and wide participation and emancipatory policies for older adult learning. Kulmus (2021) is of the view that learning in later years and further training are seen as essential for the self-determined design of a career in complex working and living conditions. Based on the assumption that knowledge and skills are imparted through further training that supports shaping learners' lives. Furthermore, Kulmus (2021) view that learning in later years can offer new opportunities for older adults to engage in learning and to take responsibility that allows them to remain functional throughout their lifetime. Thereby contributing to the workforce population, human capacity development, and career advancement.

Learning in later life has gained rapid recognition within the academic fields and policy circles in Nigeria. This recognition was influenced by the Policy Guideline for Adult and Non-Formal Education Nigeria (PGANE) and National Policy on Education (NPE). These policies were adopted to guide the operationalization of adult learning within the lifelong learning context in Nigeria, as well as to give adequate recognition to later life education of older adults through continuing education. The aforementioned policies have repositioned lifelong learning for capacity building of older adults in Nigeria. This assertion is affirmed by Obayan (2010) who postulated that lifelong learning is based on the personal and occupational needs, interests and learning requirements of individuals. Despite the increasing recognition of lifelong learning in later life. There are multifaceted challenges facing it adoption in Nigeria for bridging educational gaps and deficiencies among adult learner older adults. As it widely adopted in developed countries. Aina et, al. (2023) reported that Nigeria lack of separate policy for older adults, and this creates major challenges for the elderly population. Ageing in developing countries like Nigeria faces major challenges arising from poor financial resources, cost of enrolment, location of the centres, time frame, cultural norms, family and social commitment, and lack of institutional programme to support older adults.

Statement of the Research Problem

Despite the increasing recognition of lifelong learning as a component of active ageing and social inclusion, older adults in Nigeria face significant disparities in accessing and benefiting from continuing education programmes, ranging from cost of enrolment, location of the centers, time frame, cultural norms, and family and social commitment. The elderly population in Nigeria faces numerous challenges, including psychosocial issues, healthcare access, and economic stress (Animasahun & Chapman, 2017). These disparities are evident across the southern and northern

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regions of the country has hindered participation among older adults in continuing education. However, limited empirical research exists comparing the lifelong learning needs of older adults enrolled in continuing education programmes across these two regions. Understanding these regional differences is critical for designing inclusive, context-responsive educational policies and practices that promote equitable learning opportunities for ageing populations across Nigeria.

Research Questions

This study relates to a novel approach for addressing key research questions:

RQ1. What is the regional policy of lifelong learning in the later years of older adults in Nigeria?

RQ2. What factors motivate older adults' participation in continuing education programmes for learning in the later years?

RQ3. What are the challenges and prospects of lifelong learning needs in the later years of older adults?

Literature Review

This study presents a novel approach to reviewing literature on the current state of the art that has been highly discussed or debated in academic fields and policy circles. The literature, studies and research findings selected are relevant, current, and generalizable, drawn from peer-reviewed journals and official reports of some international organizations led credence to the current state of the art. The following databases were used: ProQuest, Web of Science, Education Resources Information Center (ERIC), and Social Sciences Citation Index (SSCI). A large and growing body of literature has investigated lifelong learning. The OECD (2023) justified this claim that lifelong learning is crucial for addressing the challenges of rapid technological change and bridging the learning gap among adult learners. According to the OECD (2023) policy outlook, lifelong learning has become increasingly important as digital transformation and automation reshape learning. The policy buttressed that continuous learning throughout adulthood is essential for maintaining learning and adapting to new skill requirements in the digital age. In this regard, lifelong learning is considered a prerequisite for continuous learning and skills development, which are paramount for socio-economic survival for an individual to function throughout a lifetime in a knowledge-driven society. Zhi Yong et al. (2024) affirmed this assertion that lifelong learning is characterized by continuously pursuing knowledge, skills, and competencies beyond the first job. In this fast-paced, technological era, facilitated by globalization and the rise of the knowledge economy, governments, employers, and employees assign significant value to lifelong learning. The authors further buttressed that lifelong learning has risen as an essential cornerstone for developing people and society, with a particular focus on skills learning, and is vital in equipping individuals with the necessary competencies to navigate the dynamic demands of the modern workforce. In this wise, lifelong learning is a critical foundation for workforce skills development to navigate a technology-driven knowledge economy.

Furthermore, Kulmus (2020) conducted a study on positive age images in German adult education as a room for responsibility and commitment. The author found that learning through further education and training aims to promote the participation of older adults in lifelong learning courses and also to support them in maintaining and updating their skills, preparing them for new activities, and imparting new skills required for them. Similarly, Midtsundstad and Nielsen (2019) researched lifelong learning and the continued participation of older Norwegian adults in employment. Their study investigated the effects of lifelong learning on employment and labour market participation using a longitudinal study using individual register data from Statistics Norway. Although the effects of upgrading seem to vary according to older adults' participation in acquired basic skills or a degree from upper secondary school or tertiary school, the overall effect seems to be positive.

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Bora, Kim, and Baumgartner (2019) reviewed the literature on the informal learning of older adults in using mobile devices. The authors postulated that mobile devices are tools that adults use to engage in informal learning. Therefore, older adults learn better in a learning environment that affords self-paced instruction and satisfies their various learning needs. In recent times, mobile devices are becoming popular and ubiquitous, the research focuses on the uses of mobile devices for informal and lifelong learning of old adults. The literature reviewed by Jin, Kim, and Baumgartner is closely related to the present study because it aimed to explore how lifelong learning needs influence the later years of older adults for career attainment.

In addition, Abdullahi (2015) conducted a study on inclusive lifelong education in skill development and labour force performance in Nigeria. The study relied on cross-national survey data, and results from the analysis revealed that inclusive lifelong education had a great premium in the skill development of the labour force, who enrolled in adult education programmes. Abdullahi (2015) noted that lifelong learning remains a key driver for the social inclusion of older adults in the mainstream of society. For this reason, concerted efforts should be made to sustain and improve later-life learning for older adults. In this regard, lifelong learning is considered a prerequisite for the sustainable development and career aspirations of the citizenry of a nation.

Theoretical Framework

This study was guided with two theories, namely:
Adult Learning Theory by Malcolm Knowles (1980)
Experiential Learning Theory by David A. Kolb (1984)

Adult Learning Theory: This theory is related to the study because adult learners have motivation towards learning such as personal goals and interests. Knowles' theory is well aligned with the learning needs of older adults enrolled in continuing education programme. Knowles' principles remain influential and align with the learning needs of older adults in modern learning practices, highlighting the need for tailored educational approaches for adults (Knowles et al., 2024). Adult learning in later life is viewed as an opportunity for spiritual growth and self-reconstruction. Andragogy theory is evident in its application to diverse learning contexts, including online environments and continuing education for older adults (Parrott, 2005). Knowles theory aims to answer the research question on motivating factors for older adults' participation in continuing education programmes for learning in the later years.

Experiential Learning Theory: Kolb's experiential learning theory is related to the lifelong learning needs of older adults enrolled in continuing education programmes. This theory shares a significant relationship with the preferences of older adults seeking lifelong learning opportunities for career goals. Older adults often have a strong desire to stay mentally active and learn new skills. Kolb's experiential learning theory provides a four-stage learning cycle: concrete experience, reflective observation, abstract conceptualization, and active experimentation (Gates, 2015). This approach is especially relevant for older adults in continuing education, as it emphasizes the importance of practical application and reflection on experiences (Lee & Kim, 2009).

The two theories discussed above are significant for exploring the interaction between the independent variable and dependent variable. Also, aim to guide the collection of qualitative data on the learning needs of older adults. The above theories strive to guide the collection of qualitative data on the experiences of employees with informal learning methods. Furthermore, this study goes beyond the state of the art to advance understanding of the impact of lifelong learning needs on older adults, as evidently shown in the literature reviewed and empirical findings and builds on the

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theoretical framework. The following were identified as the novelty of this study. No comparative study currently exists between Southern and Northern Nigeria on lifelong learning needs. This research seeks to fill this gap by developing a pioneering policy framework for integrating lifelong learning into the Nigerian curriculum. Moreover, there is no research examining older adults' participation and enrolment in continuing education using the Southern and Northern regions of Nigeria as a case study. This research aimed to address these gaps and promote knowledge transfer.

Research Methodology

Research Design

A cross-sectional research design was adopted for this study, anchored on an explanatory sequential design using qualitative data. This explains in sequence how issues in one finding lead to another finding. Thomas (2023) defines mixed-method research design as a process in which the researcher collects data from many different individuals at a single point in time, by observing variables as they occur without manipulation or influencing them. The justification for using a cross-sectional research design is to have in-depth information and knowledge about a population at a single point in time.

Sample Selection of Participants

The target population for the study consisted of male and female older adult age 40-60 years who enrolled in continuing education programmes at various institutions, colleges and adult education centres and were selected for one-on-one interviews (qualitative data). A multi-stage sampling procedure was used to determine the sample size, divided into four stages:; Stratified random sampling was used to select two regions of Nigeria, namely Southern and Northern.; Two states were purposively selected from each of the two regions. States selected includes Southern (Lagos, Rivers and Anambra States) and Northern (Kano, Borno and Kwara States). Making a total of six states.; The snowball sampling technique was used to select five voluntary participants (older adults) from each of the states earlier selected. Because there are few numbers or population of older adults enrolled in continuing education programmes. Making a total of thirty (n=30) respondents selected for one-on-one interviews (qualitative data), without bias for gender, age, or social status; A purposive sampling technique was used to select three (n=3) experts for the interview in every programmes area namely: (n=1) course facilitator, (n=1) programme organiser, and (n=1) administrator respectively.

Ethical Consideration

The researcher sought permission and approval to conduct the study from the authorities in the respective institutions, colleges and adult education centres across the six states selected. Consent of the participants was sought, in the course of the interview. This study adhered to all ethical considerations as well as complied with all regulations guiding the ethics of research. All information provided was treated with the utmost confidentiality.

Data Collection and Analysis

Key Informant Interviews (KII) were used for data collection. The interview questions were concise and aligned with the main research questions. All responses were recorded verbatim and transcribed for analysis. The essence of using qualitative data is to provide in-depth information and knowledge from the respondents. Psychometric properties of the interview guide were ascertained to ensure accuracy and consistency. The items in the Key Informant Interview (KII) guide were validated by experts in the fields of adult education, measurement and evaluation. The interview was carried out by the researcher and five research assistants who are familiar with the interview procedures. Qualitative data (interviews) were analyzed using NVivo software for systematic coding and thematic analysis to extract facts, in-depth information, and opinions of the respondents.

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Presentation of Results

This section presented a thematic analysis of the research questions on the general opinions of the respondents who participated in the study.

RQ1. What is the regional policy of lifelong learning in the later years of older adults in Nigeria?

The qualitative analysis of RQ1 revealed that there is no regional policy focus on ageing learners in Nigeria, other than the national policy of education (NPE, 2013) as expressed by experts in the interview conducted. This calls for policy advocacy, stakeholder engagement, and inclusive frameworks that acknowledge the unique learning needs of older populations across both regions.

RQ2. What factors motivate older adults' participation in continuing education programmes for learning in the later years?

Thematic analysis of responses from (n=30) participants revealed five core themes that explain the factors motivating older adults' participation in continuing education programmes across Southern and Northern Nigeria. A dominant theme was personal fulfilment and self-worth, economic empowerment, social interaction and community belonging and family encouragement, as expressed by older adults seeking learning to gain more knowledge. These themes highlight a complex interplay of intrinsic and extrinsic motivations that shape older adults' engagement in lifelong learning.

RQ3. What are the challenges and prospects of lifelong learning needs in the later years of older adults?

The interviews conducted with (n=30) respondents uncovered a dual narrative of challenges and prospects in meeting the lifelong learning needs of older adults in their later years. The following challenges were revealed includes: limited policy support and institutional neglect, inaccessible learning materials, high cost of enrollment, location of learning centers, Cultural beliefs that older adults are too old to learn, and complex lesson plans. These were extracted from the responses of the respondents during the interview. In addition, prospects and impacts of lifelong learning in the later years for older adults in Nigeria are: improved self-worth, cognitive stimulation, and social inclusion, while also empowering them economically through vocational skills, enhancing their civic engagement, promoting healthy ageing, and increasing health awareness.

Discussion of Findings

The first finding from RQ1 revealed that there is no regional policy focus on ageing learners in Nigeria, other than the national policy on education (NPE, 2013), as expressed by experts in the interview conducted. The absence of state policy on older adult learning is a particular problem facing their participation in any form of learning in Nigeria. This calls for policy advocacy, stakeholder engagement, and inclusive frameworks that acknowledge the unique learning needs of older populations across both regions. This finding support from the European Union's Green Paper on Ageing (2021) stresses the importance of addressing the educational and lifelong learning needs of older adults at both national and regional levels. The policy underscores the importance of learning as a lifelong process and older adults should be provided with opportunities to reskill and upskill in line with changing personal and societal demands (European Commission, 2021). This policy framework corroborates with the research found above and advocates for inclusive approaches to learning across the life course and encourages the development of regional policies.

The finding from RQ2, thematic analysis of responses (n=30) from participants revealed that personal fulfilment and self-worth, economic empowerment, social interaction and community belonging and

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family encouragement are factors that motivate older adults' participation in continuing education programmes for learning in the later years. This finding is supported by research conducted by Billet and Choy (2011), who explained that integrating lifelong learning and experiences in education settings could enable adult learners to enrich and extend their existing knowledge, access and learn knowledge that meet the learning needs required to function throughout the lifetime. In the same vein, Abdullahi (2015) also noted that lifelong learning provides a platform for acquiring knowledge, cultural transmission, and development of skills and understanding to enable the recipient to function throughout their lifetimes. Furthermore, Chua, Soo, & Raza (2024) reported that lifelong learning is fast becoming a natural route for adult learners to maximize their skills to remain competitive in this ever-changing job market. This assertion affirmed that adult learners are better equipped with 21st-century knowledge to enhance their skills, job security, confidence, and marketability as key benefits derived from enrolling in continuing education for lifelong learning; their studies must align with their occupational needs.

Findings from RQ3 revealed that the limited policy support and institutional neglect, inaccessible learning materials, high cost of enrollment, location of learning centers, Cultural beliefs that older adults are too old to learn, and complex lesson plans. The result was in line with the findings of Okoye (2012) noted that social changes, economic needs, and limited support for the ageing population further complicate the situation (Okoye, 2012). In the broader African context, adult learners struggle with adapting to new environments, technologies, and processes in formal learning settings. Additionally, identity and cognitive aspects pose significant challenges for adult learners (Zikhali, 2019). The prospects and impacts of lifelong learning in the later years offer older adults in Nigeria which includes: improved self-worth, cognitive stimulation, and social inclusion, while also empowering them economically through vocational skills, enhancing their civic engagement, promoting healthy ageing, and increasing health awareness. These findings align with the study of Narushima et al. (2016) who affirmed that lifelong learning plays a crucial role in promoting active ageing; participation in non-formal education can positively impact psychological wellbeing, even for vulnerable individuals (Narushima et al., 2016). Lifelong learning opportunities can help mitigate social isolation, cognitive decline, and age discrimination in later life (Formosa, 2021). To address these issues, policymakers should consider strengthening educational frameworks, providing supportive policies, and integrating sustainable development philosophies into education at all levels (Osunwusi, 2020). Overall, promoting lifelong learning opportunities for older adults can contribute significantly to active ageing and societal development.

Conclusion

This study compared lifelong learning needs in the later years of older adults enrolled in continuing education programmes in Southern and Northern Nigeria. Research has shown that lifelong learning has emerged as a critical mechanism for fostering behavioral change and enhancing the well-being of older adults in Nigeria, aligning with global perspectives on active ageing and social inclusion. Despite its recognized benefits, such as improved self-worth, cognitive stimulation, economic empowerment, and social engagement, significant barriers persist, including limited policy support, high enrollment costs, inaccessible learning materials, and cultural biases that deem older adults unsuitable for education. The absence of region-specific policies, as highlighted by the lack of frameworks beyond the National Policy on Education (NPE, 2013), underscores the urgent need for inclusive, region-sensitive policy frameworks that address the unique needs of ageing learners and promote equitable access to lifelong learning opportunities across Nigeria.

Recommendations

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Based on the findings of this study and the conclusion reached, below are the recommendations made:

1. The policymakers at both national and sub-regional levels should develop implementable lifelong learning policies that recognize the learning needs of older adults and should be embedded in state education development plans and aligned with global best practices such as the EU's age-inclusive learning frameworks.
2. The educational providers and adult education centers should leverage motivational factors such as personal fulfilment, economic empowerment, social interaction, religious engagement, and family encouragement to design flexible, relevant, and community-based learning programmes. Incorporating practical, interest-based, and vocational content into curricula can enhance participation.
3. The government and stakeholders should invest in learning facilities or infrastructure, mobile learning units, financial support, and accessible digital tools tailored to older learners. At the same time, NGO should be involved to encourage public-private partnerships to expand and sustain lifelong learning opportunities for Nigeria's ageing population.

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Development and Validation of Attitudes and Behavioural Measurement Scales on Artificial Intelligence Integration in Mathematics Teaching among Pre-Service Teachers in Abuja, Nigeria

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Abstract

The increasing use of artificial intelligence (AI) in education has created a need for concise, context-specific measures of teachers' orientations toward AI use. However, existing instruments often combine attitude, behavioural intention, perceived usefulness, self-efficacy, anxiety, and other acceptance-related constructs. This study developed and evaluated a concise measure of Attitude Toward Use (ATT) and Behavioural Intention to Use (BIU) artificial intelligence in mathematics teaching and learning among pre-service mathematics teachers. A quantitative cross-sectional survey was conducted with 221 pre-service mathematics teachers from higher institutions in the Federal Capital Territory, Abuja, Nigeria. Items were generated from the Technology Acceptance Model and relevant literature, subjected to expert evaluation, and examined using separate one-factor measurement models. Model fit was assessed using x^2, CFI, TLI, RMSEA, and SRMR, while reliability was evaluated using McDonald's coefficient omega. The initial ATT model demonstrated inadequate fit, but substantial improvement was obtained following item refinement (CFI = .990, TLI = .938, SRMR = .019, RMSEA = .120). The retained ATT indicators loaded from .528 to .818, with ω = .715. The BIU model demonstrated stronger fit ($x^2(5)$ = 11.455, CFI = .986, TLI = .972, RMSEA = .076, SRMR = .025), with factor loadings ranging from .588 to .773 and ω = .786. The findings provide preliminary evidence for concise, construct-specific measures of ATT and BIU toward AI use in mathematics teaching and learning. The BIU scale demonstrated stronger measurement performance, whereas the ATT scale requires further validation using independent samples.

Keywords: Artificial intelligence; behavioural Intention; attitude; mathematics, pre-service teachers

Introduction

The educational significance of artificial intelligence (AI) increasingly depends not only on its technical capabilities but also on whether teachers are willing to incorporate it into meaningful instructional practice. This issue is particularly consequential in mathematics education, where AI can support lesson preparation, instructional resource development, mathematical explanation, problem solving, assessment, and feedback. The emergence of generative artificial intelligence (GenAI) has expanded these possibilities while raising questions about how prospective teachers evaluate AI use and whether they intend to incorporate it into their future professional practice (Deshen et al., 2026). For pre-service mathematics teachers, who are preparing to teach in increasingly technology-mediated environments, understanding these orientations is therefore both an educational and measurement concern. Importantly, the availability of AI does not by itself establish meaningful educational integration; such integration also depends on educators' evaluations of its use and their intentions to employ it. UNESCO (2023) accordingly emphasises human agency, pedagogical appropriateness, equity, safety, and responsible use in the integration of GenAI into education.

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Teacher education provides an important context for examining these issues because pre-service teachers are developing professional orientations that may inform their subsequent classroom practices. Research has increasingly examined prospective teachers' attitudes toward AI and their intentions to use it, but these constructs have been operationalised differently across studies (Bui et al., 2025; Zhang et al., 2023). This variation raises a fundamental measurement question: when the objective is to determine whether future teachers are favourably disposed toward AI use and whether they intend to employ it, what precisely should constitute the indicators of these constructs? The question is especially relevant in mathematics education because AI use involves mathematical and pedagogical judgement. Although AI can assist with generating examples, exploring solution strategies, preparing learning activities, and developing instructional resources, teachers remain responsible for evaluating the mathematical accuracy and pedagogical appropriateness of AI-generated outputs (Cevikbas & Kaiser, 2026). Thus, a general favourable orientation toward AI does not necessarily represent a favourable evaluation of its use in mathematics education, just as an intention to use AI for general academic purposes does not necessarily imply an intention to integrate it into mathematics teaching. The behavioural referent of measurement must therefore be specified to distinguish general technological acceptance from acceptance of AI use within a particular professional domain (Stein et al., 2024).

The Technology Acceptance Model (TAM) provides an established theoretical foundation for explaining technology acceptance. Davis (1989) developed and validated measures of perceived usefulness and perceived ease of use and proposed these beliefs as fundamental determinants of user acceptance of information technology. Davis et al. (1989) subsequently compared TAM with the Theory of Reasoned Action and examined relationships among attitudes, subjective norms, perceived usefulness, perceived ease of use, behavioural intentions, and computer use. Their findings showed that behavioural intention was related to subsequent system use, while perceived usefulness exerted a substantial influence on intention. Perceived ease of use also contributed to intention, although its effect diminished over time. The authors further found that attitude did not add substantially to the prediction of intention once the effects of the other TAM variables were considered. The present study does not seek to reproduce or test this predictive structure. Rather, it focuses on developing concise measures of respondents' evaluations of AI use and their intentions to use AI in mathematics education. Perceived usefulness and perceived ease of use are consequently treated as theoretically relevant antecedent beliefs rather than indicators of behavioural intention.

The measurement of attitudes toward AI has expanded considerably, but existing instruments differ in construct definition and dimensionality. Suh and Ahn (2022), for example, developed the Scale of Attitude Toward Artificial Intelligence (SATAI) and conceptualised AI attitudes across cognitive, affective, and behavioural dimensions. Grassini (2023) subsequently demonstrated the feasibility of a brief four-item AI attitude measure, while also illustrating the importance of maintaining construct boundaries in concise instruments. Stein et al. (2024) further demonstrated the relevance of factor-structure and wording considerations in measuring general AI attitudes. Among pre-service teachers, Aktay et al. (2024) identified dimensions relating to benefits, risks, and use, while Mukherjee and Dasgupta (2024) considered general views, applications, benefits, and concerns. Collectively, these studies show that AI attitude has been operationalised according to different theoretical and contextual assumptions. A comparable issue arises in measuring behavioural intention. Chai et al. (2024), for example, developed an Artificial Intelligence Learning Intention Scale and distinguished behavioural intention to learn AI from other AI-related dispositions. Mishra and Anthony (2024) likewise examined AI and ChatGPT use in academic contexts, demonstrating the importance of

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specifying the activity associated with intended use. An intention to learn AI, use ChatGPT for academic work, and integrate AI into classroom teaching may all reflect technology acceptance, but they represent different behavioural referents. The broader literature reinforces this distinction. Naseri and Abdullah (2024) highlight TAM, the Theory of Planned Behavior, and the Unified Theory of Acceptance and Use of Technology as relevant frameworks for understanding AI adoption in education. Contemporary research also examines perceived usefulness, perceived ease of use, self-efficacy, AI literacy, anxiety, social influence, readiness, and facilitating conditions as factors associated with AI-use intentions (Ayanwale et al., 2024; Liu et al., 2026; Tootkaboni & Maghsoudi, 2025). These variables may explain intention but are conceptually different from intention itself. Similarly, Villaceran and Himang (2025) empirically separated perceived usefulness, perceived ease of use, and intention to use AI Copilot. Research involving pre-service teachers has also situated behavioural intention within specific activities such as lesson planning and teaching (Mnguni et al., 2025; Ramnarain et al., 2025; Wang et al., 2025).

Against this background, the present study focuses on the development and validation of a concise measure of Attitude Toward Use (ATT) and Behavioural Intention to Use (BIU) artificial intelligence in mathematics education among pre-service mathematics teachers. Guided by TAM and informed by contemporary research on AI attitude and behavioural-intention measurement, the study focuses on respondents' evaluations of AI use and their intentions to use AI in mathematics learning and teaching. The resulting instrument is intended to provide a focused measurement foundation for research on AI integration in mathematics teacher education.

Attitude Toward Use (ATT)

ATT represents an individual's evaluation of engaging in a particular technology-use behaviour. In the original TAM, Davis et al. (1989) examined attitude toward using computer technology alongside perceived usefulness, perceived ease of use, behavioural intention, and actual system use. Although their empirical findings led to a more parsimonious TAM in which attitude was not retained as a direct predictor of behavioural intention, the construct remains relevant in research concerned with individuals' evaluations of technology use. Importantly, ATT differs from beliefs about what a technology can provide and from the intention to perform the corresponding behaviour. AI research demonstrates considerable variation in how attitudes are conceptualised. General AI-attitude studies have examined individuals' favourable and unfavourable evaluations of AI, including broader perceptions of its benefits, risks, and implications (Grassini, 2023; Schepman & Rodway, 2020; Sindermann et al., 2021). Such measures provide useful evidence about general orientations toward AI, but they do not necessarily capture evaluations of using AI for a specified educational activity. This distinction becomes more important in teacher education, where attitudes may concern AI generally, its educational applications, or its integration into particular teaching practices.

Studies involving pre-service teachers further illustrate this contextual variation. Guan et al. (2025), for example, examined attitudes toward AI integration alongside AI literacy and self-efficacy, highlighting the conceptual distinction between an individual's evaluation of AI and their knowledge or confidence in using it. Other research has reported relationships between AI-related attitudes and behavioural intention among teachers and pre-service teachers, including pre-service mathematics teachers (Mosia et al., 2026; Qudratuddarsi & Meivawati, 2025). Similar relationships have been reported in other educational and professional contexts (Emon & Khan, 2025; Labrague & Al Harrasi, 2025). However, evidence that attitude is associated with intention does not make the two constructs interchangeable.

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A key issue emerging from the literature is therefore referent specificity. An attitude toward AI in general reflects a broad evaluation of the technology, whereas attitude toward use concerns the evaluation of engaging in a specified technology-use behaviour. For pre-service mathematics teachers, the relevant behaviour involves using AI within mathematics learning and teaching. This may include lesson preparation, mathematical explanation, problem solving, assessment, or instructional resource development. Consequently, general positivity toward AI cannot automatically be interpreted as a positive evaluation of using AI in mathematics education. For the present study, ATT is therefore conceptualised as a focused evaluative construct referring specifically to the use of AI in mathematics learning and teaching. This specification provides a clearer construct boundary than broader measures of general AI attitudes and supports its measurement as a construct distinct from behavioural intention to use AI.

Behavioural Intention to Use (BIU)

Behavioural intention to use (BIU) refers to an individual's intention to perform a specified technology-use behaviour. In technology acceptance research, behavioural intention has been examined as an immediate antecedent of actual system use; Davis et al. (1989), for example, found that behavioural intention was related to subsequent computer use within their comparison of the TAM and the Theory of Reasoned Action. Davis (1989) further established perceived usefulness and perceived ease of use as central beliefs underlying technology acceptance. Together, these foundations distinguish the intention to perform a technology-use behaviour from the beliefs and evaluations that may contribute to that intention. Research involving pre-service teachers similarly demonstrates that behavioural intention is associated with attitudinal and other cognitive determinants of technology use. Teo (2010), for example, reported a substantial influence of attitude toward computer use on pre-service teachers' intention to use technology within an integrated TAM–Theory of Planned Behavior framework. More recent research has extended this relationship to artificial intelligence (AI) within specific educational practices. Ramnarain et al. (2025) found that attitude toward AI use, AI literacy, subjective norm, perceived behavioural control, and perceived usefulness significantly predicted pre-service science teachers' intention to use generative AI in inquiry-based teaching. Mnguni (2025) similarly examined pre-service Life Sciences teachers' intentions to integrate AI into teaching and identified attitudinal, normative, and contextual factors associated with such intentions. These studies indicate that behavioural intention is more meaningfully interpreted when the intended behaviour is explicitly situated within a particular educational context.

Contemporary AI research also demonstrates substantial variation in the factors used to explain behavioural intention. Wang et al. (2025), for instance, integrated TAM, UTAUT, and Expectation-Confirmation Theory to examine pre-service teachers' sustained intention to use ChatGPT, highlighting the roles of social influence and facilitating conditions. Such explanatory models reinforce an important measurement principle: determinants of behavioural intention should not be treated as components of the intention construct itself. Perceived usefulness, social influence, facilitating conditions, AI literacy, perceived behavioural control, and attitude may explain or influence BIU, but they are conceptually different from the intention to perform the behaviour. Behavioural intention must also be distinguished according to its behavioural referent. Intention to learn AI, use AI for lesson planning, employ ChatGPT for academic work, integrate AI into inquiry-based teaching, and use AI for mathematics teaching and learning represent related but non-equivalent intentions (Odai et al., 2024; Tang, 2024; Yurt & Kaşarcı, 2025). For pre-service mathematics teachers, BIU therefore requires a sufficiently specific referent to capture the

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prospective use of AI within mathematics-related learning and teaching activities (Zheng et al., 2025). In the present study, BIU is conceptualised as a focused intention to use and integrate AI tools in mathematics learning and teaching. This specification maintains a clear boundary between behavioural intention and the attitudes, beliefs, capabilities, and contextual conditions that may account for it, providing a coherent basis for its separate measurement from attitude toward use.

Relationship Between ATT and BIU

ATT and BIU are conceptually related but distinct constructs in technology-acceptance research. ATT concerns an individual's evaluation of performing a specified technology-use behaviour, whereas BIU concerns the intention to perform that behaviour. Davis et al. (1989) examined both constructs within their comparison of the TAM and the Theory of Reasoned Action, while subsequent research has demonstrated that their empirical relationship can vary across models and contexts. Thus, although a favourable evaluation of technology use may be associated with stronger behavioural intention, the two constructs should not be treated as interchangeable. Evidence from educational settings supports an association between attitudes and behavioural intention. Teo (2010), for example, reported that attitude toward computer use substantially influenced pre-service teachers' intention to use technology within an integrated TAM–Theory of Planned Behavior framework. Gurer (2021) similarly found that attitudes toward technology were associated with intention among pre-service mathematics teachers. More recent AI-focused studies have reported comparable relationships. Sun et al. (2025) identified attitude as an important determinant of pre-service teachers' intention to use generative AI, while Ramnarain et al. (2025) reported a significant relationship between attitudes toward AI and intention to integrate generative AI into inquiry-based teaching. In the Nigerian higher-education context, Zakariya et al. (2026) likewise found that students' attitudes toward computer-based testing were related to, but distinguishable from, their conditional intention to continue using the technology.

The distinction between ATT and BIU is particularly important for measurement because factors associated with intention are not necessarily indicators of intention. Perceived usefulness, perceived ease of use, self-efficacy, social influence, facilitating conditions, and AI literacy may contribute to the formation of behavioural intention, but each represents a conceptually different construct. Likewise, a favourable attitude toward AI does not necessarily imply an intention to use AI for a particular educational purpose. The behavioural referent must therefore remain explicit when both constructs are measured. Accordingly, the present study specifies ATT as an evaluative response toward using AI in mathematics learning and teaching, while BIU represents the intention to use or integrate AI within those activities. This distinction provides the conceptual basis for developing separate indicators for the two constructs and helps prevent the conflation of evaluation, intention, and the factors that may influence technology adoption.

Research Methodology

Research Design

The study adopted a quantitative cross-sectional survey design to develop and validate a concise measure of pre-service mathematics teachers' ATT and BIU, AI in mathematics teaching and learning. Data were collected at a single point in time using a structured questionnaire. The analysis focused on evaluating the measurement properties of the two theoretically distinct constructs within the TAM, with particular attention to their factor structure and reliability.

Study Context and Participants

The study was conducted among pre-service mathematics teachers enrolled in three higher institutions in the Federal Capital Territory (FCT), Abuja, Nigeria: a university, a college of education,

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and an open higher institution. The institutions were selected to represent different forms of higher education and teacher preparation within the study context. The sample comprised 221 pre-service mathematics teachers, including 71 (32.1%) from the university, 73 (33.0%) from the college of education, and 77 (34.8%) from the open higher institution. By gender, 109 (49.3%) participants were male and 112 (50.7%) were female. Eligibility was restricted to students enrolled in mathematics teacher education programmes in the participating institutions.

Instrument Development

The development process was guided by the TAM and informed by relevant theoretical and empirical literature on technology acceptance, attitudes toward artificial intelligence, and behavioural intentions to use AI in educational contexts. The development procedure followed a sequential process comprising: (1) theoretical specification of the constructs; (2) generation of candidate items; (3) expert evaluation and preliminary content validation; (4) revision of the candidate items; (5) administration of the revised questionnaire; (6) empirical examination of the measurement structure using confirmatory factor analysis (CFA); (7) item evaluation and theoretically justified model refinement; and (8) assessment of the reliability of the resulting scales. The items were therefore treated as theory- and literature-informed indicators requiring empirical evaluation rather than as automatically valid measures.

Theoretical Specification of the Constructs

The operational definitions of ATT and BIU established in the preceding conceptual framework were used as the basis for item development. ATT was operationalised as respondents' overall dispositions towards the use of AI in mathematics teaching and learning, whereas BIU was operationalised as their intention to use or integrate AI in mathematics teaching and learning. The items were generated deductively from the TAM and relevant empirical literature. During item development, attention was given to maintaining clear boundaries between the two target constructs and related technology-acceptance variables. Candidate ATT items were required to represent respondents' evaluations or affective orientations toward AI use, while candidate BIU items were required to represent future-oriented intentions to use or integrate AI in mathematics teaching and learning. Antecedent beliefs, capabilities, and contextual conditions were not intended to serve as indicators of ATT or BIU. The theoretical specification therefore provided the conceptual criteria against which candidate items were subsequently evaluated for relevance, clarity, behavioural specificity, and construct alignment.

Item Generation

An initial pool of eight candidate items was generated deductively from the operational definitions of ATT and BIU and informed by the relevant theoretical and empirical literature. At this stage, four items were specified for ATT and four items for BIU. The candidate items were designed to capture respondents' evaluations of AI use and their future-oriented intentions to use AI in mathematics teaching and learning.

The initial ATT items were:

1. ATT01: Using AI in Mathematics education is a good idea.
2. ATT02: I have a positive attitude toward using AI in Mathematics learning and teaching.
3. ATT03: Using AI in Mathematics education would be beneficial.
4. ATT04: I enjoy the idea of using AI for Mathematics learning.

The initial BIU items were:

1. BIU01: I intend to use AI tools in learning and teaching Mathematics in the future.

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2. BIU02: I will regularly use AI tools for Mathematics-related tasks.
3. BIU03: I plan to integrate AI tools into my future Mathematics teaching.
4. BIU04: I would recommend the use of AI tools for Mathematics education.

The candidate items were subsequently subjected to expert evaluation before empirical administration. During this process, particular attention was paid to potential conceptual overlap among items and related constructs. For example, an item referring to the benefits of AI could potentially reflect perceived usefulness rather than attitude alone, while an item referring to recommending AI could represent a social or advocacy response rather than the respondent's own behavioural intention. These considerations informed the subsequent evaluation and empirical assessment of the items.

Data Collection and Analysis

Data were collected from pre-service mathematics teachers enrolled in the three participating higher institutions in FCT, Abuja. Following the necessary institutional permissions, the researchers visited the participating institutions and administered the questionnaires directly to eligible participants using a paper-based format. Before administration, participants were informed about the purpose of the study, the voluntary nature of participation, and the confidentiality of the information provided. They were also informed that participation was solely for research purposes and would have no consequences for their academic standing. Clear instructions were provided to facilitate accurate completion of the questionnaire. Completed questionnaires were collected immediately after administration and screened for completeness and suitability for analysis. A total of 221 valid questionnaires were retained for statistical analysis. The responses were subsequently coded and entered into the statistical software for analysis. The data were analysed using procedures appropriate for scale development and validation. Preliminary data screening was conducted before assessment of the measurement models. The factor structure of the ATT and BIU scales was examined using latent-variable modelling, while scale reliability was assessed using McDonald's coefficient omega (ω).

Presentation of Results

Measurement Model of Attitude Toward Use

The measurement structure of the Attitude Toward Use (ATT) construct was examined using a one-factor latent-variable model in which the observed ATT items were specified as indicators of a common underlying construct. The initial specification (Model 1) demonstrated inadequate fit to the observed data, $x^2(5) = 55.271$, $p < .001$, RMSEA = .213, 90% CI [.165, .266], CFI = .854, TLI = .707, and SRMR = .069. The pattern of fit indices indicated substantial discrepancy between the hypothesised measurement structure and the observed response covariance matrix, particularly as reflected in the low CFI and TLI and elevated RMSEA. Item-level examination identified ATT01 as having a relatively weak standardized factor loading of .370. The item was therefore removed from the measurement model. Examination of the residual structure subsequently indicated an association between the errors of ATT04 and ATT05, which was specified in the revised model on substantive and measurement grounds. The resulting Model 2 was then evaluated using the same fit criteria.

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Table 1

The goodness of fit statistics for one-factor ATT scale

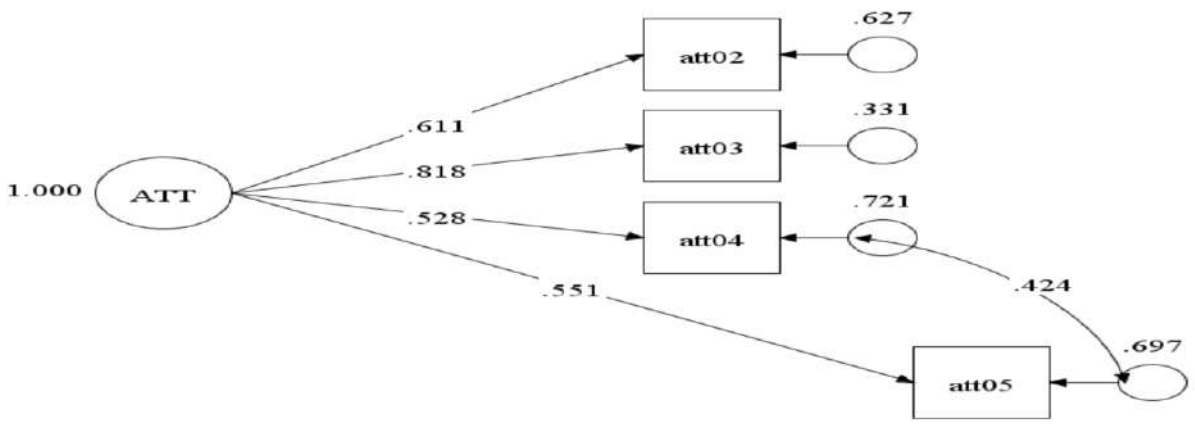
Global fit statistics	Model 1	Model 2
Chi-square		
Estimate (χ^2)	55.271	4.187
Degrees of freedom (df)	5	1
p-value	<.001	0407
χ^2 / df	11.0542	4.187
RMSEA (Root Mean Square Error of Approximation)		
Estimate	.213	.120
90 percent confidence interval	[.165, .266]	[.020, .248]
Probability RMSEA <= .05	<.001	.099
CFI/TLI		
CFI (Comparative Fit Index)	.854	.990
TLI (Tucker-Lewis index)	.707	.938
SRMR (Standardized Root Mean Square Residual)	.069	.019

The revised model showed a substantial improvement in fit relative to Model 1. The chi-square statistic decreased from 55.271 to 4.187, while CFI increased from .854 to .990 and TLI from .707 to .938. SRMR decreased from .069 to .019, indicating substantially lower standardized residual discrepancy. RMSEA also declined from .213 to .120, although the revised estimate remained above the conventional threshold for close approximate fit. The 90% confidence interval for RMSEA was [.020, .248], indicating uncertainty around the approximate-fit estimate. Overall, the revised specification provided a markedly better representation of the observed data than the initial model, particularly according to the comparative and residual fit indices.

The standardized parameter estimates for the revised ATT measurement model are presented in Figure 3.

Figure **1**

Standardised estimates of model parameters for the 1-factor ATT scale



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Figure 3 presents the standardized parameter estimates for the revised one-factor ATT measurement model. All four retained indicators demonstrated positive factor loadings on the latent ATT construct, ranging from .528 to .818. The strongest loading was observed for att03 (λ = .818), followed by att02 (λ = .611), att05 (λ = .551), and att04 (λ = .528). Thus, each retained item demonstrated a meaningful relationship with the underlying ATT construct, although the magnitude of association varied across indicators. The corresponding standardized residual variances were .627, .331, .721, and .697, respectively, indicating that the latent factor accounted for approximately 37.3%, 66.9%, 27.9%, and 30.4% of the variance in att02, att03, att04, and att05. A residual covariance of .424 was specified between att04 and att05, indicating shared item-specific variance beyond that explained by the common ATT factor. Overall, the standardized estimates support the retention of the four indicators, while also indicating that att04 and att05 contain some residual covariance that should be considered when interpreting the revised measurement structure.

Measurement Model of Behavioural Intention to Use

The Behavioural Intention to Use (BIU) scale was evaluated using a one-factor latent-variable model, with the observed items specified as indicators of a common underlying intention to use or integrate AI in mathematics teaching and learning. The model yielded $x^2(5) = 11.455$, $p = .043$, with a x^2/df ratio of 2.291. The corresponding fit indices were RMSEA = .076, 90% CI [.013, .136], CFI = .986, TLI = .972, and SRMR = .025.

Table **2**.

The goodness of fit statistics for one-factor BIU scale

Global fit statistics	Model Statistics
Chi-square	
Estimate (χ^2)	11.455
Degrees of freedom (df)	5
p-value	.0431
χ^2 / df	2.291
RMSEA (Root Mean Square Error of Approximation)	
Estimate	.076
90 percent confidence interval	[.013, .136]
Probability RMSEA <= .05	.188
CFI/TLI	
CFI (Comparative Fit Index)	.986
TLI (Tucker-Lewis index)	.972
SRMR (Standardized Root Mean Square Residual)	.025

The results indicated that the one-factor BIU model provided an adequate representation of the observed data. Although the chi-square test was statistically significant, the comparative fit indices were high, with CFI = .986 and TLI = .972. The SRMR of .025 indicated low standardized residual discrepancy, while the RMSEA of .076 suggested acceptable approximate fit. Taken together, the pattern of fit statistics supported the proposed unidimensional measurement structure of BIU. The standardized parameter estimates for the BIU measurement model are presented in Figure 4.

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Figure **2**

Standardised estimates of model parameters for the one-factor BIU scale

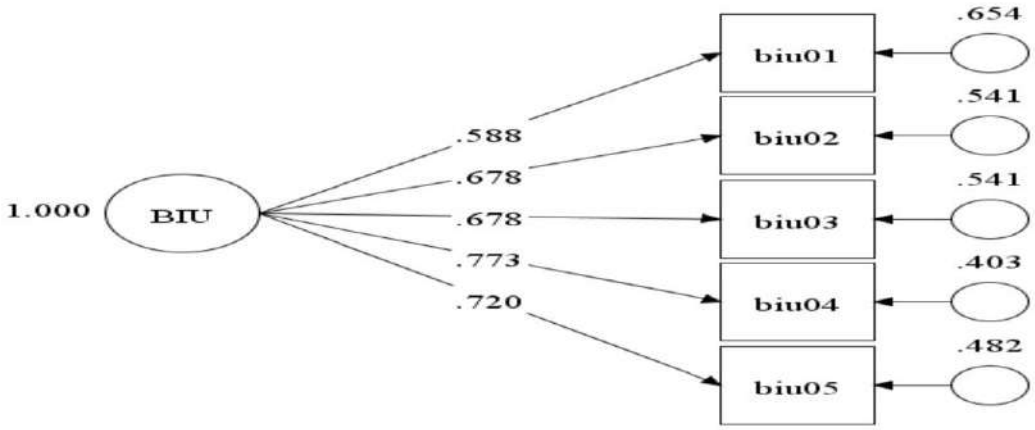


Figure 4 presents the standardized parameter estimates for the one-factor BIU measurement model. All five indicators demonstrated positive and substantive factor loadings on the latent BIU construct, ranging from .588 to .773. The strongest loading was observed for biu04 (λ = .773), followed by biu05 (λ = .720), while biu02 and biu03 both loaded at .678 and biu01 at .588. These estimates indicate that all retained indicators made meaningful contributions to the measurement of behavioural intention to use AI. The corresponding standardized residual variances were .654, .541, .541, .403, and .482, indicating that the BIU factor explained approximately 34.6%, 45.9%, 45.9%, 59.7%, and 51.8% of the variance in biu01 through biu05, respectively. No residual covariances were specified, suggesting that the covariance among the indicators was adequately represented through the common BIU factor. Taken together, the standardized estimates provide support for the proposed unidimensional structure of the BIU-AI scale.

Discussion of Findings

This study developed and evaluated a concise measure of Attitude Toward Use (ATT) and Behavioural Intention to Use (BIU) artificial intelligence among pre-service mathematics teachers. The findings provide initial evidence that the two constructs can be represented as distinct, theoretically bounded dimensions of AI acceptance. The BIU model demonstrated stronger overall measurement performance, while the ATT model showed substantial improvement after item refinement, although its RMSEA remained above the conventional criterion for close fit.

Attitude Toward Use

The initial ATT model demonstrated inadequate fit, but the revised model showed substantial improvement, with CFI increasing from .854 to .990, TLI from .707 to .938, and SRMR decreasing from .069 to .019. The four retained indicators loaded positively on ATT, with loadings ranging from .528 to .818, indicating that each item contributed meaningfully to the latent construct. These findings provide qualified support for measuring attitude toward AI use as a unidimensional construct. The result is consistent with previous AI-attitude research demonstrating that attitudes toward AI can be measured through a relatively concise set of evaluative indicators (Schepman & Rodway, 2020; Sindermann et al., 2021; Grassini, 2023). However, the present scale differs conceptually from general AI-attitude measures because its referent is AI use in mathematics teaching and learning. This distinction is important because an individual may hold a favourable

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view of AI generally without necessarily evaluating its use positively within mathematics education. The ATT findings nevertheless require cautious interpretation. Although the revised model produced strong CFI, TLI, and SRMR values, RMSEA remained relatively high at .120. Moreover, a residual covariance was specified between att04 and att05, suggesting some shared variance beyond the general ATT factor. Thus, the revised model represents a substantial improvement over the initial specification, but should not be described as demonstrating unequivocally close fit. Replication with an independent sample is necessary to determine whether this structure is stable.

Behavioural Intention to Use

The BIU model demonstrated a stronger measurement profile. The one-factor model produced high CFI (.986) and TLI (.972), low SRMR (.025), and an RMSEA of .076, indicating acceptable approximate fit. All five indicators loaded substantially on the latent construct, ranging from .588 to .773, while the reliability coefficient was satisfactory (ω = .786). The absence of correlated residuals further supports a relatively straightforward unidimensional representation of BIU. This finding is consistent with TAM, which positions behavioural intention as a proximal construct reflecting an individual's intention to perform a specified technology-use behaviour (Davis, 1989; Davis et al., 1989). It also complements recent research on AI use among pre-service teachers, where behavioural intention has been examined in relation to lesson planning, teaching, and other educational applications (Wang et al., 2024; Ramnarain et al., 2025). The present study extends this work by defining the behavioural referent specifically around AI use in mathematics teaching and learning. Importantly, the findings support a distinction between measuring BIU and explaining BIU. Contemporary studies often incorporate perceived usefulness, self-efficacy, AI literacy, social influence, facilitating conditions, and related variables to explain intention (Ayanwale et al., 2024; Tootkaboni & Maghsoudi, 2025; Zhang et al., 2026). These variables may influence BIU but should not automatically be treated as indicators of the construct itself. The present scale therefore provides a more focused operationalisation of intention.

Implications for Measurement

Taken together, the findings support the theoretical distinction between ATT and BIU. ATT captures an individual's evaluation of using AI, whereas BIU captures the intention to engage in that behaviour. Although these constructs are theoretically related and previous studies have shown that attitude can predict intention (Teo, 2010; Gurer, 2021; Sun et al., 2025), the present study did not estimate a structural relationship between them. Its purpose was instead to establish focused measurement models for each construct. This distinction has practical implications for AI research in mathematics teacher education. A concise instrument can be useful where researchers need to assess specific acceptance constructs without introducing unnecessary dimensions. The findings therefore support the use of construct-specific measurement rather than broad acceptance instruments that combine attitudes, beliefs, capabilities, and contextual factors. The reliability coefficients obtained for ATT (ω = .715) and BIU (ω = .786) further indicate that the scales provide acceptable reliability despite their concise structure (Zakariya & Massimiliano, 2022).

Limitations and Future Research

The study has several limitations. The sample comprised 221 pre-service mathematics teachers from three higher institutions in FCT, Abuja, limiting generalisability beyond the study context. The validation also relied on a single cross-sectional sample; therefore, the reported structure requires replication and cross-validation with independent samples. Future studies should examine convergent, discriminant, and criterion-related validity and test whether the scales demonstrate measurement invariance across relevant groups. In addition, BIU represents intended, rather than

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actual, AI use. Longitudinal research should therefore examine whether BIU predicts subsequent AI integration in mathematics teaching. Future research should also investigate how perceived usefulness, ease of use, AI literacy, self-efficacy, trust, and contextual conditions relate to the two constructs without incorporating these variables into their measurement.

Conclusion

The study provides initial evidence for a concise measure of ATT and BIU toward AI use in mathematics teaching and learning among pre-service mathematics teachers. The BIU scale demonstrated a stronger and more coherent measurement structure, while the ATT scale showed substantial improvement following refinement but warrants further validation. Overall, the findings support a theoretically bounded approach in which attitude and behavioural intention are measured as distinct constructs rather than as a broad, undifferentiated form of AI acceptance.

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Effect of Maple Software on STEM Students' Problem-Solving skills in Mathematics Concepts among Science and Technical Schools in Kano State, Nigeria

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Abstract

The study investigates the effects of Maple software to enhance STEM students' problem-solving skills in mathematics in Kano science and technical schools. The study was guided by three research questions and two null hypotheses. A quasi-experimental design was adopted for the study. The population of the study comprises all SS II students in Kano State science and technical schools. Two intact classes were selected for the study from two different schools, randomly selected, that is, science and technical schools, respectively; thus, 235 students were the sample size of the study, making 115 experimental and 120 control groups. The Mathematics Problem-Solving Skills Test (MPSST) was used for data collection. The instrument was validated by experts and reliability coefficient of 0.87 was obtained using Cronbach's alpha. Mean and standard deviation were used to answer the research questions, and independent t-tests were used for testing the null hypotheses. The findings revealed that there are differences in the level of problem-solving skills among science and technical students before treatment, while Maple software improve STEM students' problem-solving skills, and the difference exists between science and technical students' problem-solving skills after treatment, is not statistically significant. The study concludes that Maple software enhances STEM students' problem-solving skills in mathematics. The study suggests that computer programs like Maple should be used in teaching mathematics.

Keywords: Maple software, STEM, Problem-Solving Skills, Mathematics.

Introduction

As science and technology are the twenty-first century's development forces, the demand for mathematics is always climbing. Mathematics is a discipline without which modern science and technology would not exist. Because of the impact mathematics has, Nigeria, like other nations, has made mathematics learning mandatory throughout primary and secondary school education (National Policy on Education [NPE] 2014). Aside from being an integral aspect of STEM education, mathematics is the language of science and technology; without it, technological advancement, including ICTs, is meaningless. The importance of mathematics in the success of STEM education cannot be overstated. To meet the challenges of the twenty-first century, several nations have advocated a STEM education paradigm that emphasizes the study of sciences, technology, engineering, and mathematics (Park et al., 2016; Kang, 2019). According to Wang et al. (2018), the United States of America (U.S.A) was the first to propose STEM education as a national development strategy to tackle the challenges of the century. Many industrialized countries, including China, South Korea, Germany, the United Kingdom, and others, have followed the lead of the United States in STEM education (Park et al., 2016; Wang et al., 2018; Kang, 2019). Nigeria, as a developing country, joined the global community in promoting Science, Technology, Engineering, and Mathematics (STEM) education for social, economic, and industrial growth (Ndinechi & Okafor, 2016;

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Umar, 2019). Many scientific and technology programs, including science and technical schools, have been built across the country to ensure the success of STEM education (Abdulrahman et al., 2017). Such schools produce science teachers, medical doctors, engineers, architects, and other professionals. The performance of those students in STEM subjects, particularly mathematics, was very impressive at the time, but history has changed. This necessitates the provision of ways out, especially for the attainment of 21st-century learning skills. The 21st-century learning skills were grouped into three: learning and innovation skills (LI skills), digital literacy skills (DL skills), and career and life skills (CL skills). Each of the categories is subdivided as follows: learning and innovation skills (LI skills) include critical thinking and problem-solving; communication skills; collaboration, creativity, and innovation, summarized as the 4Cs. Then, digital literacy skills, that is, informati on literacy, media literacy, and information and communication technology (ICT) literacy. Finally, career and life skills, which include flexibility and adaptability, initiative and self-direction, social and cross-cultural interaction, productivity, and accountability (Lamb, Maire, & Doecke, 2017), are necessary for the attainment of these learning skills. In each of these skills, problem-solving and mathematical skills are required. To this end, the study focuses on how Maple software enhances STEM students' problem-solving skills in mathematics, which combines problem-solving and Mathematics.

The mathematics teaching and learning processes received the attention of the computer program designers. Several software programs were developed to ease the teaching and learning of mathematics. Some software programs were designed for general-purpose use, such as Maple, Mathematica, MATLAB, MuPAD, and so on, while others, such as Magma, GAP, GP/PARI, and Solver, were designed for specific tasks (Hiyam et al., 2019). Maple is a general-purpose software that is classified as a Computer Algebra System (CAS) (Saparwadi et al., 2019). It is the most powerful software, besides Mathematica and MatLab, that assembles all the math engines with an affiliation that makes it possible to analyze, explore, visualize, and solve mathematical problems (Salleh & Zakaria, 2016; Wu & Li, 2018). It has over 5000 functions covering almost every area of mathematics, including calculus, algebra, differential equations, and linear algebra (www.maplesoft.com). It can improve students' achievement rapidly and prepare them for the use of technology in the classroom (Xu, 2016). Students' problem-solving skills were viewed as their ability to recognize and understand problems, as well as the strategies required to solve them. Problem-solving skills are important for educational purposes because they help students learn to solve real-life situations by applying mathematical knowledge, techniques, and skills (Darma, 2018). Problem-solving is required not only for solving mathematical problems but also for building new ideas, knowledge, and skills within and outside the mathematical context. Unfortunately, the low level of problem-solving skills among STEM students is evident in their achievement in mathematics, which contributes significantly to the overall low quality of mathematics education in Nigeria. Enhancing STEM students' problem-solving skills and mathematical achievement could be a stepping stone towards improving the mathematics discipline in Kano State Science and Technical Schools.

Theoretical Framework

Problem-solving skills were framed under cognitive learning theory. The theory has the perspective that learning takes place through the efforts of the learner. Computer-Assisted Learning Instruction (CALI) was employed, where learning is achieved through computer or Internet instruction (Seville, 2016). This type of learning allowed learners to construct knowledge through their interaction with computer programs. Many studies have revealed that mathematics

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software provides learners with constructive learning and mathematics skills and also allows students to think critically, logically, and spatially.

Statement of the Problem

For brighter future careers of STEM students in Kano State Science and Technical Schools, good problem-solving skills and academic performance in mathematics is required. In this era of emergent technology, computer-based instruction has become fundamental for modern education, providing interactive and student-centred learning experiences which traditional methods cannot. Hence, the need to incorporate such approaches in the Nigerian STEM classroom. However, mathematics instruction in these schools is still dominated by teacher-centred approaches, and there is limited use of technology tools like Maple software. Maple has features that could potentially enhance mathematical understanding and problem-solving skills, but there is no empirical evidence of its effectiveness in this regard. Therefore, this study is aimed at improving the problem-solving skills and academic achievement in mathematics of STEM students in Kano State Science and Technical Schools using Maple software. The study adopts a quasi-experimental design to find out whether or not teaching with Maple software is more effective than the conventional teaching methods.

Objective of the Study

This research work was designed to attain the following objectives, that is to:

1. Determine the level of STEM students' problem-solving skills in mathematics before treatment.
2. Investigate the effects of Maple software on STEM students' problem-solving skills in mathematics.
3. Examine the difference between science and technical students' problem-solving skills in mathematics after treatment.

Research Questions

This research work was designed to answer the following research questions:

1. What is the level of STEM students' problem-solving skills in mathematics before treatment?
2. Does Maple software enhance STEM students' problem-solving skills in mathematics?
3. Is there any mean difference in the problem-solving skills of science and technical students in mathematics after treatment?

Research Hypotheses

The following null hypotheses were developed based on the research questions highlighted and tested at the 0.05 level of significance.

$H0_1$: There is no significant difference between STEM students' problem-solving skills of those taught using Maple software and those taught using the conventional method.

$H0_2$: There is no significant difference between science students' and technical students' problem-solving skills in mathematics when taught using Maple software.

Research Methodology

The study adopted a quasi-experimental design, pretest-posttest equivalent control group design. The design is appropriate for testing the influence of independent variable over dependent variable. In this study, Maple software was used as a computer-based instruction to test whether it enhance students problem-solving skills and academic achievement. The population of the study consists of all SSII STEM students in the Kano State Science and Technical School Board (STSB), with a total number of ten thousand five hundred and sixty (10,560) as of the 2020–2021 academic session. Four schools were randomly selected, two science and two technical schools, whereas an intact class was considered the sample of the study in each school. In each of the science and technical school there is one experimental and one control group. This makes the sample size one-hundred and fifteen

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(115), making fifty-eight 58 science students and fifty-seven (57) technical students for both experiments. While the control group were one-hundred and twenty (120), making sixty-one science (61) and fifty-nine (59) technical students. The instrument used for the study was the Mathematics Problem-Solving Skills Test (MPSST), extracted from WAEC past question papers between "2010-2015." The MPSST consisted of ten open-ended questions covering the SS I and SS II mathematics curricula. The MPSST was marked based on the WAEC marking system, which was used to classify the level of the STEM students' problem-solving skills. Three experienced mathematics teachers with over 20 years of teaching experience assess the validity of the MPSSTs. It was also given to a specialist in the field of testing and measurement, both for criterion, content, and face validity. The validation was based on the items' appropriateness in terms of problem-solving skills, the difficulty level of the items, the feasibility of the items, and the correctness for attempting to answer. However, the scoring system also gave suggestions for the improvement of test items. After affecting all the corrections given by the validators, then the MPSST administered to students withing the population but different from the sample of the study for pilot testing. For reliability, pilot testing was carried out on forty (40) STEM students. The split-half method of reliability was used to measure the internal consistency of the MPSST. The reliability coefficient was 0.87, indicating that the MPSST was valid and reliable. Mean and standard deviation were used to describe the research questions. Independent t-test were used to test the hypotheses, and the data was analyzed using SPSS version 27.

Treatment Procedure and Post-test Administration

The treatment was initiated immediately after the pre-test. The experiment lasted for a period of seven weeks, with forty-five minutes spent on each lesson. In the first week, the students were introduced to some basic computer knowledge and Maple software. In the subsequent weeks, the researcher used Maple software to teach the subject following Poly's problem-solving strategy. The strategy helps students develop a deep understanding of a concept. After the treatment, MPSST was administered to the student as a post-test. WAEC exam conditions were observed during the post-testing, and each question was scored at ten (10) marks. The researcher classified the students' problem-solving abilities into nine levels, from excellent to poor. The scores were collected and organized for data analysis based on the WAEC grading system. Table 1 and Table 2 show what is required of the students as well as the marks awarded to each question and the WAEC grading system, respectively.

Table 1: Marking Scheme based on Polya's Problem-Solving Skills

Steps	Description	Marks Awarded
Understanding the Problem	What the question is all about? Which values are provided? What is asked to find? Sketch the image of the problem etc.	3
Device a Plan	Select an appropriate method to be used for finding the solution i.e. formula or a given procedure.	3
Execute the plan	Implement the selected plan i.e. workout the formula.	2
Look back	To check whether the problem is solved or not. If not cross check the procedure or find alternative and repeat the steps.	2
	Total	**10**

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Table 2: The Level of Problem-Solving Skills based on WAEC Grading system

Scores	Grade	Interpretation	Level
75-100	A1	Excellent	Level 8
70-74	B2	Very Good	Level 7
65-69	B3	Good	Level 6
60-64	C4	Upper Credit	Level 5
55-59	C5	Average Credit	Level 4
50-54	C6	Lower Credit	Level 3
45-49	D7	Upper Pass	Level 2
40-44	E8	Lower Pass	Level 1
0-39	F9	Fail	Level 0

Source: WAEC portal, 2023

Presentation of Result

The results were presented based on the research questions and corresponding hypotheses in tabular form. The hypotheses were tested at the 0.05 level of significance. R.Q. stands for research question and H0 for null hypotheses, as follows:

Research Question One: What is the level of STEM students' problem-solving skills in mathematics before and after treatment?

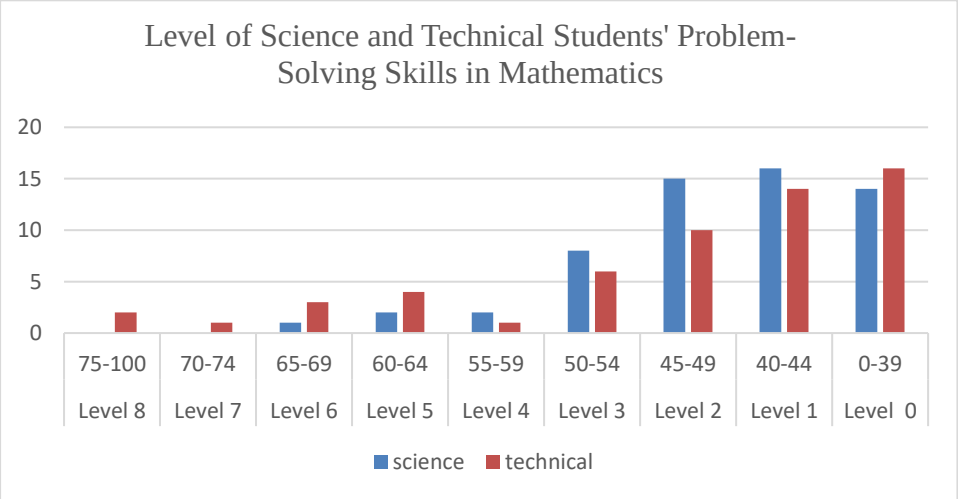


Figure 1: The level of STEM students Problem-Solving in Mathematics Skills before treatment.

A bar chart graph gives a picture of the levels of STEM students' problem-solving skills in mathematics before treatment. It shows the trend of the mathematical problem-solving skills of science and technical students towards a low level (level 0). Technical students' mathematical problem-solving skills are more likely to lead to a high level of mathematical problem-solving skills. Furthermore, the graph shows that the level of mathematical problem-solving skills of STEM students in technical schools is slightly better than their science school counterparts.

Research Question Two: Does Maple software affect STEM students' problem-solving skills in mathematics?

H_{O1}: There is no significant difference between STEM students' problem-solving skills of those taught using Maple software and those taught using conventional method.

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Table 3: Mean, Std. Deviation and independent t-test Experimental and Control Group

Variables	N	M	SD	M.diff	df	t	P	Remark
Control group	120	9.54	2.71	12.98	233	27.971	0.001	The Hypothesis is rejected
Experimental group	115	22.52	4.26					

Table 3 showed descriptive statistics describing the effect of Maple software on STEM students' problem-solving skills in mathematics. The Table showed a mean score of the control group 9.54 (SD = 2.71) and a mean score of the experimental group 22.52 (SD = 4.26), with a mean difference of 12.98. The mean difference revealed the effect of Maple software on the students' academic achievement. Furthermore, in each case the standard deviation is smaller than the mean, which indicate that there is wider coverage of the scores among the respondents. Table 3 showed independent t-test on the effect of Maple software on STEM students' problem-solving skills. It is revealed there is significant difference between the problem-solving skills of the students taught using Maple and those taught using conventional method of teaching $t(233) = 27.971, p = 0.001$.. The hypothesis stated "There is no significant difference between STEM students' problem-solving skills of those taught using Maple software and those taught using conventional method" is hereby rejected, since $p < 0.05$.

R.Q 3: Is there any significant mean difference in the problem-solving skills of science and technical students in mathematics after treatment?

Ho_2: There is no significant difference between science students' and technical students' problem-solving skills in mathematics when taught using Maple software.

Table 4: Mean, Std. Deviation and independent t-test Science and Technical Students' Problem-Solving Skills

Schools	N	$\bar{x}$	SD	M.diff	Df	t	P	Remark
Science	58	23.36	3.49	1.69	113	2.167	0.032	Reject Hypothesis
Technical	57	21.67	3.80					

Table 4 showed descriptive statistics for the differences between science and technical students' problem-solving skills in mathematics treatment reveal a mean score of 23.36 (SD = 3.49) and a mean score of 21.67 (SD = 3.80), with a mean difference of 1.69 in favor of science students. Table 4 showed independent t-test between science and technical students' problem-solving skills. It is revealed there is significant difference between the problem-solving skills of science and technical students problem-solving skills when taught using Maple $t(113) = 2.167, p = 0.032$. The hypothesis stated "There is no significant difference between science students' and technical students' problem-solving skills in mathematics when taught using Maple software" is hereby rejected, since $p < 0.05$.

Summary of Finding

1. There are significant differences in the level of problem-solving skills of science and technical students before treatment.
2. Maple software affects STEM students' problem-solving skills.
3. A significant difference exists between science and technical students' problem-solving skills after treatment, however is not much significant.

Discussion of Findings

From Figure 1, the findings reflect the degree of mathematical problem-solving skills of science and technical students in mathematics before treatment takes place. A majority of the science and

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technical students were found to have poor levels of mathematical problem-solving skills, with few students achieving high levels of mathematical problem-solving skills in favor of technical students. Table 3 showed the effect of the Maple software on the students' problem-solving skills. The descriptive statistics showed how effective the Maple software was on the STEM students' problem-solving skills, with a mean difference of 12.98 in favor of the experimental group. In addition, the independent t-test between the STEM students' problem-solving skills before and after treatment. The correlation was moderately positive, with $t(233) = 27.971, p = 0.001$. The difference was significant, and the hypothesis is hereby rejected there is significant difference between the problem-solving skill of STEM students taught with Maple software and those taught with conventional method. These findings are consistent with the study of Wu and Li (2018); Nurfalah et al., (2021); Yuliardi et al., (2024); Sawlat et ai., (2024); (Kocher et al., 2024); Usmonov and Abdufayozova, (2025); that showed a significant effect of Maple software on STEM students' learning outcomes and problem-solving skills and other studies that used different computer packages Perawansa et al., (2019). From Table 4, the result of the descriptive statistics showed the existence of differences between science and technical students' problem-solving skills in mathematics after treatment in favor of science students 1.69. However, the independent t-test showed a significant difference between the science and technical students' problem-solving skills in mathematics after treatment: $t\,(113) = 2.167, p = 0.032$. This revealed that the effect of Maple software is more on science than technical students' problem-solving skills. The researcher observed that the students showed their interest in seeing how the computer program displayed the mathematics. The finding of this study is in line with the research finding of Akanmu, (2017); Akogwu et al., (2019); Mamman & Isa, (2019); (Ni'mah et al., 2024); Kossivi, (2025), who found the positive effect of computer-based instruction on students' academic achievement, attitude and interest in mathematics.

Conclusion

Based on the findings of the study, it is concluded that Maple software affects STEM students' problem-solving skills. It is also, concluded that problem-solving skills of science students greater than that of technical students when taught using Maple.

Recommendations

1. The study recommended the need for encouraging and motivating science students in order to improve their problem-solving skills as much as their counterparts, technical students.
2. Computer programs such as Maple should be involved in the teaching and learning process as they affect students' problem-solving skills for the attainment of 21stcentury learning skills.

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Conflict of Interest

There was no funding source for this study, and the authors had no conflict of interest. All the necessary and due approvals and consents were obtained before the experiment and data collection.

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Fostering Transnational Science, Technology, Engineering and Mathematics Education: An Exploration of Climate-Smart Practices

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Abstract

This paper discusses the pressing need for a transboundary approach to tackle climate change through STEM education, which is currently limited by traditional education methods. It introduces the Climate-Smart Transnational STEM Framework, encompassing seven dimensions: Cross-border Collaboration, Localised Climate Context, Innovation for Mitigation and Adaptation, Measurement and Data, Awareness and Action, Teacher Capacity, and Equity and Access. Grounded in theories like Connectivism and Education for Sustainable Development, the framework aims to connect local climate issues with global knowledge networks, promoting a collaborative learning approach. It addresses challenges specific to Africa and the Global South, such as infrastructural inequalities and digital exclusion, while offering a conceptual model for curriculum designers and educators to align STEM education with Sustainable Development Goals. Future studies are called for to validate the framework across diverse educational and climate contexts.

Keywords: climate-smart education; STEM education; transnational education; climate literacy; systems thinking; digital learning; Global South

Introduction

Education is supposed to make learners not just for involvement in existing social and economic systems but for responding critically and creatively to complex and fast ever-evolving global conditions. Now, education requires knowledge, skills, dispositions and capacities that enable learners to examine problems, evaluate evidence, collaborate with others and develop novel and

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practical solutions. Regarding science education, these expectations are vital due to the problems like climate change, biodiversity loss, food insecurity, energy transitions, environmental degradation and technological disruption cannot be effectively addressed through lonely disciplinary knowledge. Ayua et al. (2026d) stresses the relevance of critical, creative, practical and solution-based science education for sustainable development, including the development of learners' creative minds and hands. The STEM education is needful for such relevance through creative exploration as confirmed by Ayua et al. (2026d); Ayua et al. (2026f); Terhemba and Ayua, (2025) that this can show the potential of learner-centred science experiences for strengthening creative thinking and practical competencies. Science, Technology, Engineering and Mathematics (STEM) education pave way for proper educational platform for solving these problems because it brings together scientific inquiry, technological applications, engineering design and mathematical reasoning. Unified STEM education can create opportunities for learners to investigate authentic problems instead of treating scientific and mathematical knowledge as disconnected bodies of content. Joined STEM educational approaches can support students' creativity, engagement, critical thinking, problem-solving and application of knowledge to real-world situations (Anwar, 2022; Han et al., 2022; McLure et al., 2022). The advancement of sustainability agenda further makes stronger the case for connecting STEM education with environmental and climate-related problems. Climate change creates an important framework for this integration. This requires physical and biological processes which need scientific understanding; technologies for observation, communication, classification and mitigation; engineering solutions for resilience, infrastructure and renewable energy; and mathematical process for analysing trends, risks and environmental data.

Climate change is basically transnational since greenhouse-gas emissions, atmospheric processes, ocean systems, food systems, migration, water resources and technological transitions cross national boundaries. Educational responses could enable learners to understand both the local manifestations and global interconnectedness of climate change. There can be climate education that is interdisciplinary, action-based and connected to learners' live experiences. According to Padhra and Tolouei (2023) climate-change education can be embedded across higher-education programmes instead of limiting it to specialised courses. Moreso, Ma and Chen (2023) show the problems of climate-change education in the Global South, where educational responses must be sensitive to local environmental, economic and institutional conditions. Climate education can become a powerful framework for developing STEM competencies while making stronger learners' climate literacy and skilful for action. Despite this potential, STEM education is still uneven. The disciplines may be taught separately, climate issues may be presented as general environmental topics instead of STEM design problems, and chances for students to collaborate internationally may remain limited. McLure et al. (2022) reveal that integrated STEM projects make authentic problem-solving opportunities, but practice is still dependent on teacher capacity, curriculum structures, resources and institutional support. At the same time, dissimilarities in connectivity, devices, laboratories, teacher readiness and teacher preparation and funding may prevent learners in lower-resource situations from participating meaningfully in digitally mediated international STEM experiences.

This paper addresses the yawning gap by presenting a framework that integrate STEM, climate-smart practice and transnational collaboration. It builds on the creative science learning, practical competencies, digital education and inclusive STEM participation (Ayua et al., 2026e). Studies address creative exploration, AI-supported learning, digital classrooms, gender and STEM participation, and inclusive science education (Ayua et al., 2026a; Terhemba et al., 2025; Terhemba

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& Ayua, 2025). These strands create a useful basis for covering the discussion from locally situated innovative science teaching to globally connected, climate-oriented STEM education. The focus of this paper is that climate-smart STEM education can connect local environmental realities to global knowledge networks. However, how can climate-smart practices be intentionally organised within STEM education to promote cross-border collaboration, climate literacy, innovation, teacher capacity and educational equity?

Climate Change as a Transnational STEM Challenge

Climate change is a scientific, technological, engineering, mathematical, social and educational problem. Comprehending fluctuations in temperature, rainfall, sea level, atmospheric composition and ecosystem dynamics needs scientific inquiry and interpretation of empirical evidence. Making available and sustaining renewable-energy systems, climate-resilient infrastructure, water-management technologies and adaptation technologies needs engineering and technological innovation. Also, monitoring trends, modelling risk and evaluating interventions need mathematics, statistics and computational methods. Therefore, climate change creates a natural setting for integrated STEM learning instead of teaching students isolated concepts such as energy, heat transfer, measurement, statistics or environmental science, teachers can organise learning around reliable problems. Students, for instance, may examine how rising temperatures can affect their community, analyse local temperature data, develop a low-cost cooling intervention, calculate energy requirements and communicate their findings to students in another country experiencing a different climate problem. Researches show developed STEM-based learning materials around global warming and reported improvements in students' STEM literacy and the STEM-based physics teaching materials addressing climate change improved high-school students' climate literacy (Hakim et al., 2023; Tari et al., 2023). This means that engagement with climate-related data and visualisations can improve climate knowledge and situated interest among secondary students. The relevance of climate education is beyond knowledge acquisition, therefore, scientific literacy for climate action necessitates learners to interpret evidence, identify uncertainty, evaluate competing claims, consider ethical implications and participate in up-to-date decision-making. That is why Tasquier et al. (2022) and Sezen-Barrie et al. (2025) conceptualise scientific literacy as ability for change-making in relation to complex societal problems like climate change and that climate and environmental education requires transformational approaches that connect scientific comprehension with action, justice and learners' lived realities.

From Disciplinary STEM to Integrated and Sustainability-Based STEM

Integrated STEM (iSTEM) education is an approach that connect disciplines around meaningful problems instead of just placing Science, Technology, Engineering and Mathematics beside one another. The division is vital, however, teaching four STEM subjects within the same institution does not really produce integrated learning. Integration of STEM education requires learners to mobilise knowledge from various domains to explore, design, test, evaluate and communicate solutions. According to McLure et al. (2022) school-based iSTEM education projects generally involve authentic problems, interdisciplinary knowledge and design-oriented learning and Han et al. (2022) also confirms that sustained integrated STEM practice can be continued only when teachers develop shared practices and institutional support. Furthermore, positive learning outcomes associated with an iSTEM curriculum is usually united in middle-school life science (Anwar, 2022). The continuity programme may create an additional rationale for integration. Addressing environmental problems, STEM education can become a mechanism instead of just preparing students for examination-based STEM careers. There is need and interest in integrating Education for Sustainable Development with

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STEM education (Habibaturrohmah et al., 2023) and there is evidence on STEM-based teaching and the Sustainable Development Goals that STEM can contribute to critical thinking, creativity, innovation and problem-solving relevant to sustainable development. The conceptual framework is therefore presented in Figure 1.

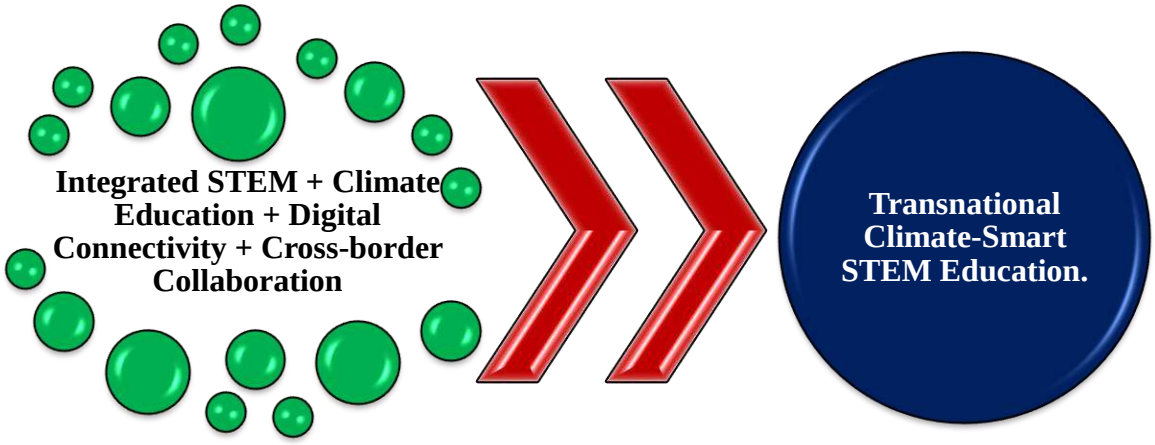


Figure 1: Conceptual Framework

This formulation in Figure 1, moves the discussion beyond conventional integrated STEM by adding two dimensions that is usually treated separately: climate action and transnational learning.

Climate-Smart Education and Climate Literacy

Climate-smart education as shown in Figure 1 simplifies the educational practices that enable learners to understand climate procedures, explore climate-related risks, develop mitigation and adaptation solutions, use evidence and technology responsibly, and participate in individual and collective climate action. Climate literacy can be more than just knowing that climate change is taking place. It involves comprehending climate systems, interpreting evidence, identifying human and environmental consequences, evaluating solutions and developing the ability to make well-versed decisions. Climate literacy can be made stronger through appropriately designed STEM learning as shown the connection in Figure 1. STEM-based physics teaching materials improved climate literacy among high-school students and low-cost Do It Yourself (DIY) model kits could improve conceptual understanding of climate change among preservice teachers (Srichaitung, et al., 2025 & Hakim et al., 2023). In this regard teachers' ability is very vital as Ibourk et al. (2025) examined teachers' climate-change knowledge and self-efficacy and highlighted the importance of learning technologies in supporting teachers' ability to teach climate change. More to this, Rap and Blonder (2025) investigated technology acceptance in climate-change teaching and reveals that teachers' perceptions use of technology can influence how digital tools are amalgamated into climate-related teaching. That is to say that, climate-smart STEM education can address two correlated abilities including learner climate literacy and teacher climate-pedagogical ability.

Transnational STEM Education

As presented in Figure 1, Transnational STEM Education (T-STEM-E) simply has to do with learning, teaching, researching and curriculum activities that connect learners, educators, researchers or institutions across national boundaries around STEM-related knowledge and problems. As shown in Figure 1, it may involve virtual classrooms, joint projects, international competitions, shared datasets, collaborative research, student mobility, joint curriculum development, virtual laboratories

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and co-designed problem-solving activities. The transnational dimension presented in Figure 1 is vital to climate change because climate problems are simultaneously local and global. For instance, a flood-prone Nigerian community may examine rainfall patterns and drainage systems while collaborating with learners in another country investigating flooding, coastal erosion or water management. The two groups may encounter different environmental conditions but use common STEM processes to collect evidence, analyse data and develop solutions. Digital technologies presented in Figure 1 can make such collaboration feasible. Learners can have access to experimentation when physical facilities are unavailable or geographically inaccessible through Virtual laboratories. Physical and virtual investigations can support conceptual knowledge acquisition (Muilwijk & Lazonder, 2023). Furthermore, Flegr et al. (2023) reveals the educational value of combining virtual and video-based experiments in remote STEM learning and May et al. (2023) further conceptualised online laboratories as sociotechnical-pedagogical environments requiring link among technology, pedagogy and institutional conditions. Transnational learning cannot be reduced to technological connectivity, however, for effective collaboration, it requires shared objectives, culturally responsive pedagogy, equitable participation, teacher coordination, data governance, appropriate assessment and institutional commitment.

Theoretical Foundation

Theoretically, this paper was anchored on theoretical framework presented in Figure 2.

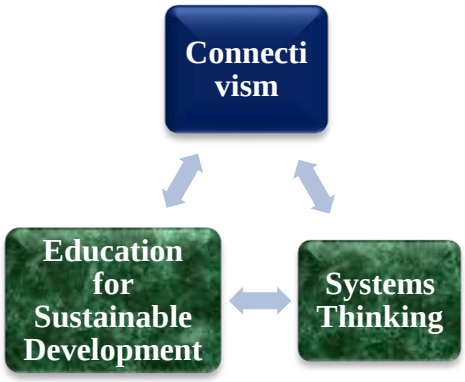


Figure 2: Theoretical Framework

Siemens' (2005) Theory of Connectivism as presented in Figure 1 conceptualises learning as the formation and maintenance of connections among people, information sources, digital environments and knowledge networks. Connectivism is vital to transnational STEM education because digital networks allow learners to access information and collaborate beyond the boundaries of their classroom and country. Learners can connect to climate datasets, scientific publications, remote laboratories, experts, teachers and international peers through climate-smart STEM education. This theory explicates why knowledge cannot be treated as something located exclusively in a learner. Climate knowledge can be shared across scientific institutions, environmental monitoring systems, communities, governments, technological platforms and international communities. Learning constitutes knowing where to source for vital knowledge, how to evaluate it, how to connect it to another knowledge, and how to use it ethically. Studies on AI-supported science education and digital classrooms reinforce the modern relevance of technology-mediated learning and digital participation in STEM education (Ayua et al., 2026; Terhemba & Ayua, 2026). As shown in Figure 2, Education for Sustainable Development (ESD) highlights knowledge, competencies, values and action for solving social, environmental and economic problems. Its importance to this framework

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lies on systems thinking, participation, responsibility and action. Climate-smart STEM education operationalises ESD by changing climate challenges into authentic STEM problems. Learners do not learn what climate change is but they can examine or explore local evidence, examine alternative responses, design solutions and consider the implications of their decisions. According to Stouthart et al. (2023) preparing teachers to use socio-scientific problems like climate change is central to developing sustainability-based pedagogical ability. STEM-ESD integration also shows a growing attention to connecting STEM learning with sustainability challenges (Habibaturrohmah et al., 2023). Climate change requires interacting systems instead of isolated variables since temperature, rainfall, agriculture, water, energy, health, infrastructure and economic activity interact in complex ways. Systems thinking as presented in Figure 2 encourages learners to recognise relationships, feedback loops, interdependencies and unintended consequences. Making stronger therefore, the conceptual basis of transnational STEM education because learners can compare how similar climate processes interact with different social, geographical and technological systems. Together, Connectivism, ESD and systems thinking in Figure 2 create complementary explanations: connectivism which is the network through which knowledge is accessed and shared, while ESD is the sustainability-based purpose of learning and systems thinking shows how learners understand interconnected climate systems.

The CLIMATE-SMART Transnational STEM Framework

This paper presents **Climate-Smart Transnational STEM Framework**, comprising seven interdependent dimensions as shown in Figure 3.

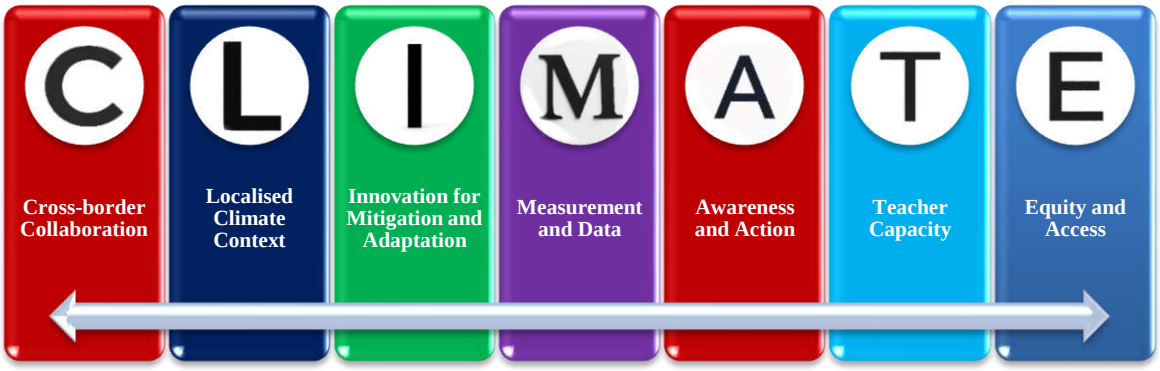


Figure 3: The Climate-Smart Transnational STEM Framework

Figure 3 shows that the framework is not conceived as a linear activity in which one dimension is completed before another. However, the dimensions interact dynamically such that local climate problems stimulate investigation; investigation produces data; data support innovation; innovation requires collaboration; collaboration produces shared learning; and the whole process depends on teacher ability and equitable access.

C — Cross-border Collaboration

From Figure 3, cross-border collaboration is the defining of transnational component of the framework that learners and teachers could have structured opportunities to work with peers and institutions beyond their immediate geographical setting. Possible activities are presented in Figure 4.

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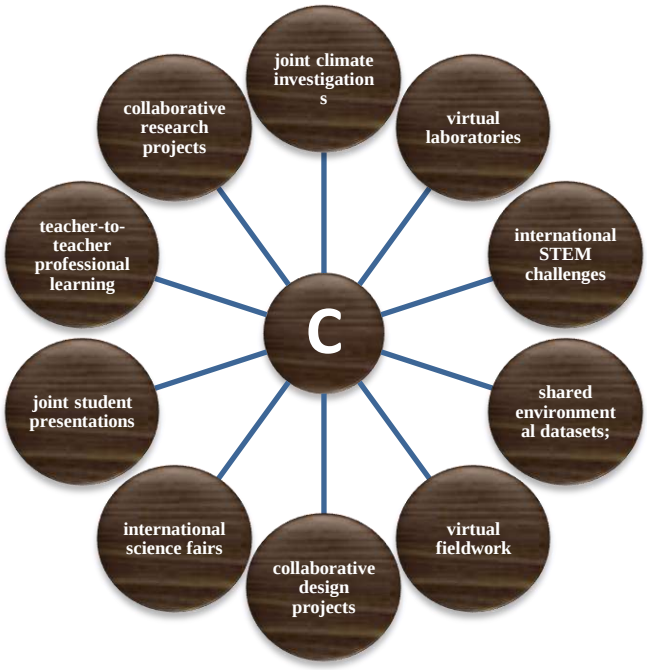


Figure 4: C — Cross-border Collaboration

The Figure 4 shows that the goal is not international interaction for its own sake but collaboration may create educational value by allowing learners to compare environmental conditions, exchange interpretations and co-develop solutions. The advent of networks such as the Network for Emergent Socio-Scientific Thinking (NEST, 2024) reveals the potential of collaborative networks that work across borders, disciplines and generations to address complex environmental problems.

L — Localised Climate Context

Global climate education becomes meaningful when learners can connect it to problems they can observe. Localised climate setting is presented in Figure 5.

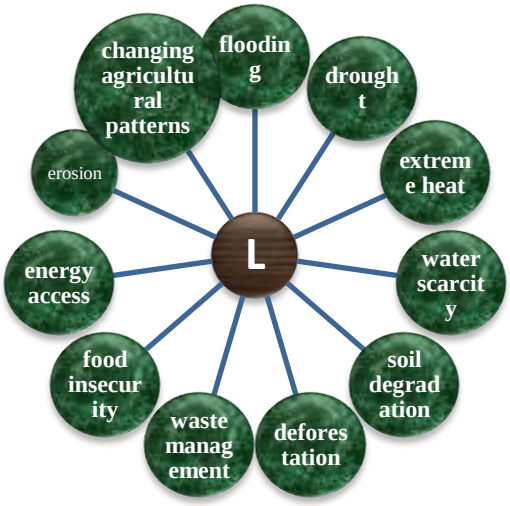


Figure 5: L — Localised Climate Context

As shown in Figure 5, the local setting can serve as the starting point for inquiry instead of the boundary of learning. For instance, a learner may examine flooding in Makurdi and subsequently

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compare rainfall, drainage and flood-management data with learners in another flood-prone region. This has created a local-to-global learning architecture.

I —Innovation for Mitigation and Adaptation

The innovation dimension transforms STEM learning from problem recognition into solution-based development, the students may engage in activities as shown in Figure 6.



Figure 5: **I —Innovation for Mitigation and Adaptation**

Figure 5 reveal that innovation can be evaluated not only by technical novelty but also by feasibility, affordability, environmental sustainability, cultural appropriateness and potential social impact. The study on creative exploration is vital here because it divulge the value of learner-centred approaches for developing creative and practical competencies in science education (Terhemba & Ayua, 2025; Ayua et al., 2026e).

M — Measurement and Data

Climate-smart STEM education requires physical evidence; therefore, Students can be taught practically as presented in Figure 6.

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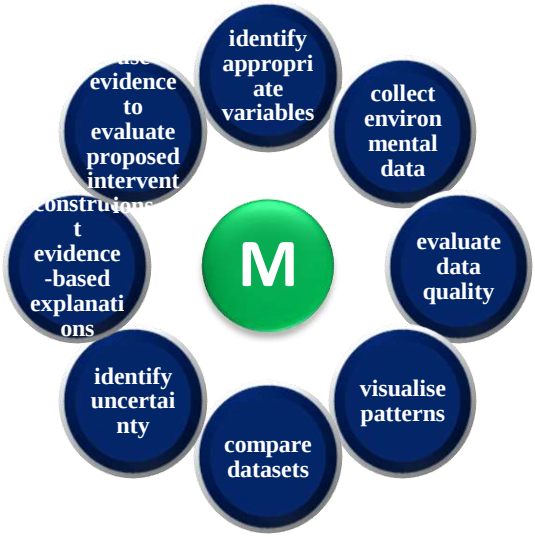


Figure 6: M — Measurement and Data

Figure 6 reveals that where infrastructure permits, students can use sensors, geographic information systems, remote sensing, Internet of Things (IoT) devices and computational tools. Artificial intelligence (AI) can support pattern recognition and data analysis, but students must learn to evaluate AI-generated outputs critically and thoughtfully. Climate learning suggest that data visualisation can make students' climate knowledge and motivation.

A — Awareness and Action

Climate education can connect knowledge with ethical action. Awareness requires understanding climate processes, risks and consequences; while action requires using this knowledge to make and evaluate decisions. The possible action-based projects is presented in figure 7.



Figure 6: **A — Awareness and Action**

As present by Figure 6, it means that the emphasis can be on evidence-informed action rather than symbolic activities.

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T — Teacher Capacity

Teachers are necessary because they are the core practice mechanism of this framework. Even cultured climate-STEM curricula may have limited effect if teachers lack content knowledge, technological competence, interdisciplinary pedagogical knowledge or confidence in teaching controversial and complex climate problems. This teacher development is therefore presented in Figure 8.

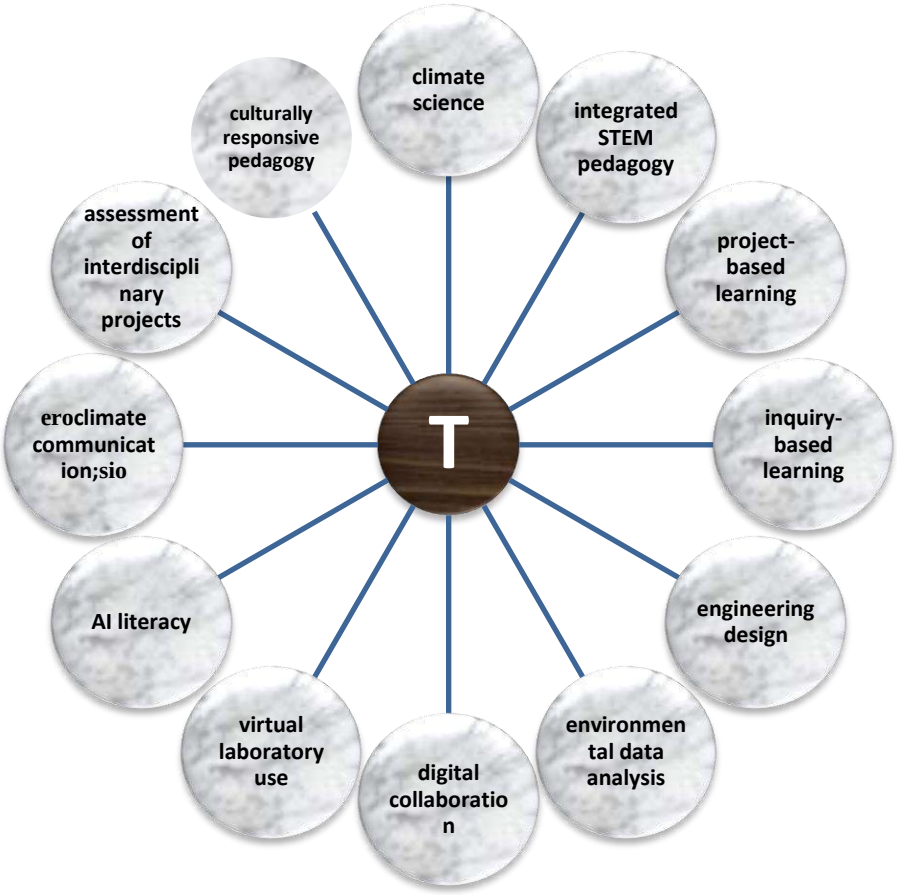


Figure 8: T — Teacher Capacity

The Figure posits that the importance of teacher in this regard cannot be overemphasize, that is why Ibourk et al. (2025) show the importance of teacher climate-change knowledge and self-efficacy, while Rap and Blonder (2025) identify the role of technology acceptance in climate-change teaching.

E — Equity and Access

It is good to note that equity is not an additional component of climate-smart STEM education but it is a condition for its legitimacy. Transnational STEM programmes can by mistake reproduce educational inequalities if participation depends on high-speed internet, expensive devices, international travel or well-resourced institutions, therefore equity is shown in Figure 9.

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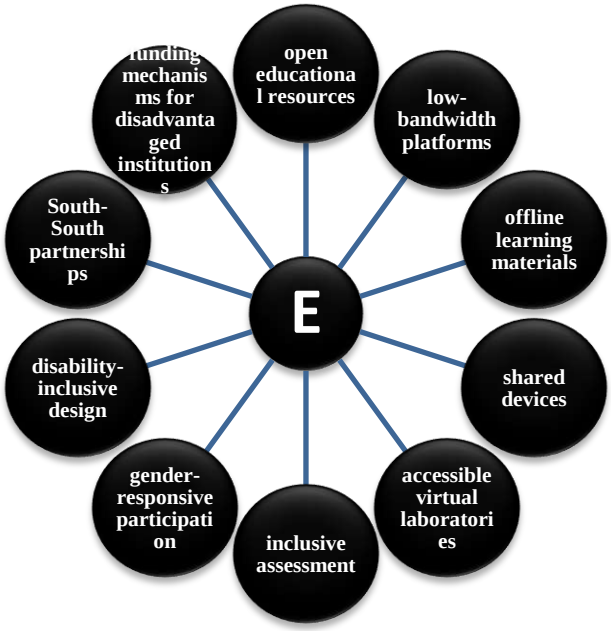


Figure 9: **E — Equity and Access**

This dimension present in Figure 1 is vital for African and other Global South settings, where digital and infrastructural differences can hinder participation in international education networks. Also, there are studies that shows the importance of digital inclusion and gender equity in STEM participation, including the potential and risks associated with AI-supported digital education (Ayua et al., 2026b; Terhemba & Ayua, 2026).

Operational Pathway of the Framework

The seven dimensions can be operationalised through learning cycle as shown in Figure 10.



Figure 10: Operational Pathway of the Framework

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This operational pathway of the framework in Figure 10 shown in cycle distinguishes the Climate-Smart Transnational STEM Framework from conventional climate-awareness programmes. Here, the learner is not just positioned as a recipient of climate information but as an investigator, designer, collaborator and potential change-maker.

Virtual Laboratories and Digital Platforms

Digital technologies can cover transnational STEM education beyond visible mobility. Virtual laboratories can direct learners to conduct simulations, analyse experimental data and explore phenomena that may be difficult or expensive to investigate physically. According to Muilwijk and Lazonder (2023) both physical and virtual investigations can backup to conceptual knowledge acquisition. The usefulness of virtual and video experiments for STEM learning when conventional laboratory access is constrained and the successful online laboratories depend on the interaction between technological, pedagogical and institutional factors (Flegr et al., 2023 & May et al., 2023). Regarding the Climate-Smart Transnational STEM Framework, virtual laboratories can complement instead of automatically replacing physical experiences. In situations where physical facilities are available, blended laboratory models may provide the strongest opportunities for connecting observation, simulation and real-world measurement.

Artificial Intelligence (AI), Data and Climate-Smart STEM

AI presents extra potentials for climate-smart STEM education, it can assist learners in organising large datasets, identifying patterns, generating simulations, supporting coding and exploring alternative scenarios. It can facilitate communication among learners participating in transnational projects. Nevertheless, AI could be merged within a framework of scientific integrity and critical evaluation. It is needful for students to understand that AI-generated information may contain errors, biases or unsupported claims. studies highlight perceived benefits for research self-efficacy and attitudes, while their work on scientific integrity stresses the ethical challenges created by generative AI in science education research (Ayua et al., 2026c). Climate-smart AI education may add: AI literacy; source verification; data provenance; transparency of AI use; privacy protection; responsible data sharing; bias awareness; and academic and scientific integrity. AI can function as an augmentation tool, not as a substitute for scientific reasoning.

Africa and the Global South: Contextualising Transnational STEM

The Global South shows both challenges and vital opportunities for climate-smart STEM education. Communities in Africa are experiencing climate-related problems while simultaneously confronting infrastructural and educational disparities. A globally designed STEM programme may fail if it assumes that all schools have equivalent connectivity, laboratories, electricity, devices and teacher expertise. Transnational STEM education must therefore avoid a one-directional model in which knowledge flows from highly resourced institutions to less-resourced institutions. Instead, the Climate-Smart Transnational STEM Framework advocates reciprocal knowledge exchange. Students in Nigeria for instance may contribute knowledge concerning flood management, agricultural adaptation or local ecological practices, while international partners contribute alternative technologies, datasets or analytical tools. Such collaboration positions African learners as knowledge producers instead of passive recipients. This principle is consistent on the challenges of climate education in the Global South and with scholarship advocating for more inclusive and transformative approaches to climate education (Ma & Chen, 2023).

Major Barriers to Implementation

The major barriers or hindrances for practice is highlighted in Figure 12.

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Figure 12: Barriers to Implementation

Figure 12 presented that the unequal access to broadband internet, electricity, digital devices and technical support can limit participation. National curricula may be planned by individual subjects and examination requirements, making interdisciplinary climate-STEM projects difficult to practice. Teachers may lack the climate knowledge, interdisciplinary pedagogical knowledge and digital competencies required. International projects actually need resources for connectivity, teacher training, equipment, coordination, translation, travel and data management. Transnational learning can be affected by changes in language, cultural expectations, educational traditions and communication practices. Traditional examinations may not adequately capture collaboration, design thinking, climate action, data literacy or interdisciplinary problem-solving. Short-term projects may produce enthusiasm without establishing institutional structures that sustain collaboration.

Strategies for Implementation

Here are the following strategies that can strengthen practice as presented in Figure 13.

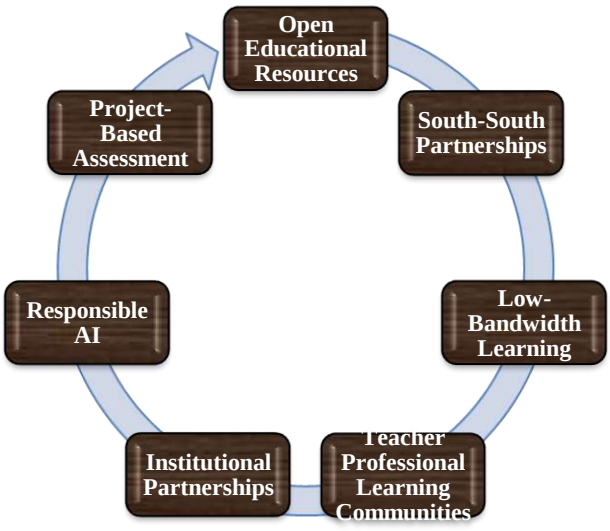


Figure 14: Strategies for Practice

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Figure 14 present that climate-STEM teaching resources can be openly licensed and adaptable to different settings. Institutions in many areas of Africa, Asia, Latin America and other Global South regions can develop reciprocal STEM-climate partnerships based on shared problems. Platforms can support asynchronous communication, downloadable resources and offline participation. Teachers from participating countries can form professional learning communities to co-design climate-STEM projects and share classroom experiences. Schools, colleges, universities, research organisations, environmental agencies and technology organisations may collaborate on long-term programmes. AI tools could be integrated with explicit instruction in scientific integrity, verification, privacy and responsible use. Assessment may include portfolios, design prototypes, research reports, data analyses, presentations, collaborative products and reflective accounts.

Implications for Curriculum Development

Curriculum developers may move from climate content being treated as an isolated environmental topic towards climate-infused STEM curricula as the example is shown in Figure 15.

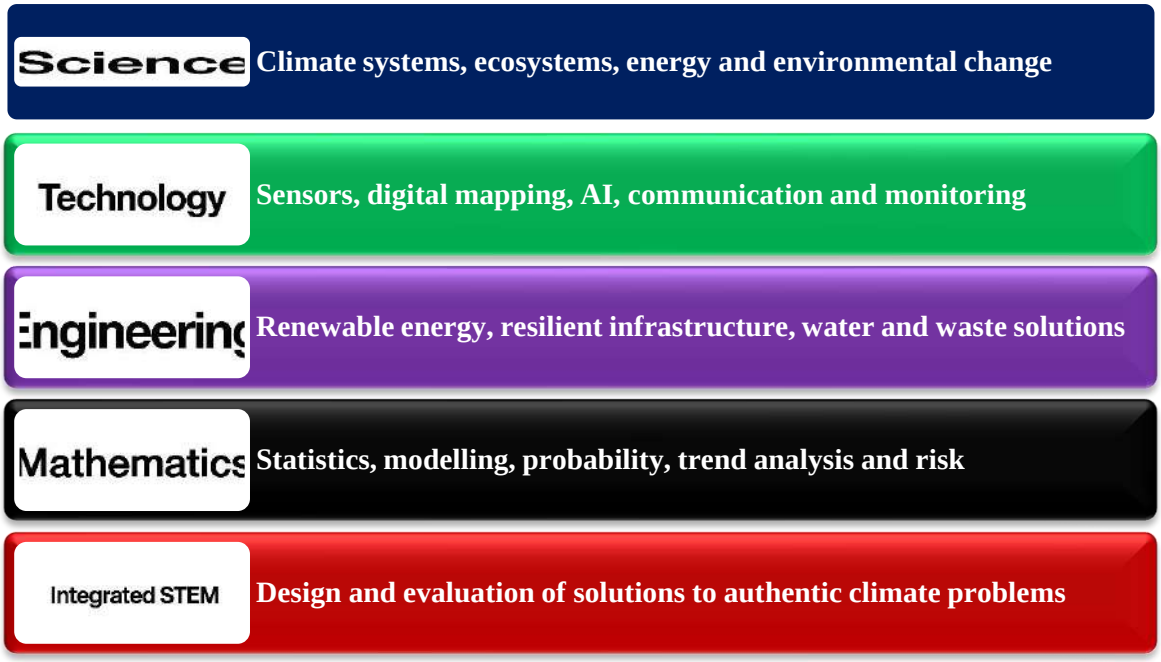


Figure 15: Implications for Curriculum Development

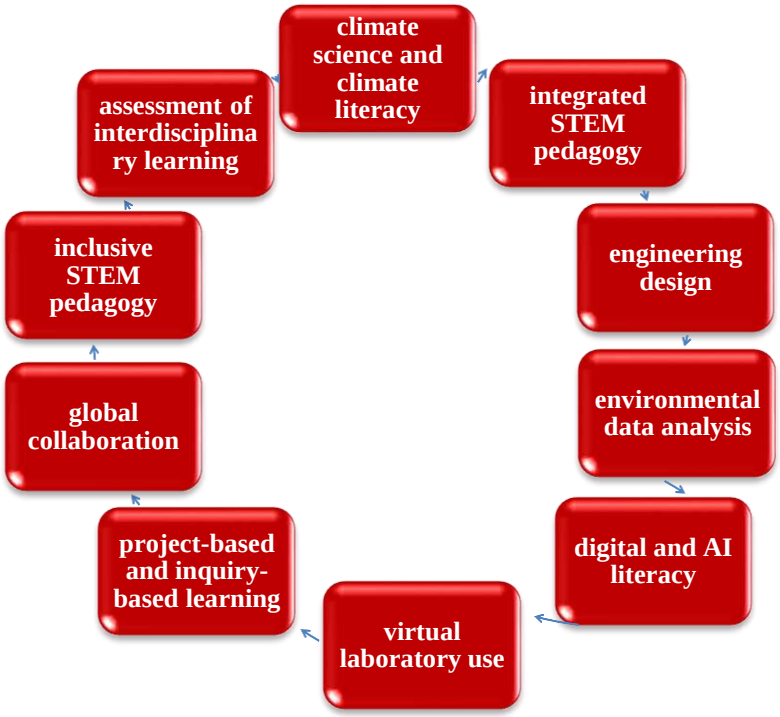
Figure 15 shows that such curriculum integration can increase the relevance of STEM education while supporting sustainability competencies.

Implications for Colleges of Education and Teacher Education

The Colleges of Education and teacher education have a vital role to play because they prepare teachers who can practice STEM and climate education in schools. Teacher education curricula can incorporate the following as presented in Figure 16.

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Figurer 15: Implications for Colleges of Education and Teacher Education

Figure 15 present that teacher candidates can participate in international virtual projects where possible. Such experiences can help them develop confidence in collaborating with educators and learners from different settings.

Policy Implications

The framework has several policy implications: national education policies could identify climate change as a cross-curricular STEM priority instead of confining it to environmental education. Governments can invest in digital infrastructure, electricity, laboratories and teacher professional development. International organisations may support equitable transnational STEM programmes that do not exclude low-resource schools. Policymakers can create mechanisms for identification of learning achieved through international virtual projects and collaborative STEM programmes. Funding mechanisms could prioritise partnerships that show reciprocal participation instead of one-way knowledge transfer.

Scholarly Contribution of the CLIMATE-SMART Framework

The input of this paper lies in integrating three areas that are often discussed separately: climate-smart education, integrated STEM education and transnational learning. Existing integrated STEM literature makes evidence that interdisciplinary STEM projects can support authentic problem-solving and student learning (McLure et al., 2022; Han et al., 2022). According to Padhra and Tolouei, (2023); Sezen-Barrie et al. (2025) posits that there is need for scientific literacy, action and contextualisation. Digital learning scholarship also shows the potential of virtual experimentation and technology-mediated learning (Muilwijk & Lazonder, 2023; Flegr et al., 2023). The framework joins these strands through a single educational architecture presented in Figure 17.

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Figure 17: Educational Architecture for the Framework

The Figure 17 revels that this provides a conceptual basis for moving from integrated STEM to climate-smart transnational STEM.

Proposed Research Agenda

Instead of being seen as an established intervention paradigm, the framework can be empirically validated. Future research can look into the following: Do students who engage in Climate-Smart projects show higher levels of STEM achievement and climate literacy than students who get traditional instruction? How well does the framework work in nations with various educational systems and climatic risks? Which professional development programs best equip educators for international STEM that is climate-smart? What effects do offline and low-bandwidth methods have on students' participation in underprivileged communities? Does the framework increase girls' and students with disabilities' meaningful involvement in STEM? Do climate-smart STEM experiences lead to long-term environmental activity, STEM identity, and climate knowledge? How might AI aid in the study of climate data while upholding learner autonomy and scientific integrity?

Conclusion

We need education responses to climate change that are scientifically sound, technologically capable, locally relevant and globally connected. STEM education offers a powerful platform for developing the knowledge and competencies necessary to investigate climate problems, analyse evidence and design mitigation and adaptation solutions. Yet, the full capacity of STEM for climate action cannot be realised when STEM disciplines are still isolated, climate education is still informational, or learning is still confined within national and institutional boundaries. This paper presents the Climate-Smart Transnational STEM Framework, comprising Cross-border Collaboration, Localised Climate Context, Innovation for Mitigation and Adaptation, Measurement and Data, Awareness and Action, Teacher Capacity, and Equity and Access The framework uses local climate challenges as entry points for STEM inquiry, and utilises digital networks to connect learners across geographical boundaries. Transnational education should not be an additional mechanism for already advantaged institutions to accumulate international opportunities. Rather, it can enable a reciprocal sharing of knowledge in which institutions and learners in Africa and other contexts of the Global South can add their own environmental knowledge, innovations and experiences. The paper conceptually

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advocates for a transition from local STEM education to globally connected, climate-smart STEM education. Such a transition can feed into the ambitions of SDG 4 through stronger inclusive and relevant quality education and SDG 13 through the development of climate literacy, adaptation capacity and informed action. The framework is a proposition that needs empirical testing. Its value may ultimately depend on whether further research shows that climate-smart transnational STEM learning can enhance learners' STEM competencies, climate literacy, creativity, collaboration, data literacy, equity of participation and ability for meaningful climate action.

Recommendations

The following recommendations were made that:

1. Governments and education authorities should develop fundable climate-smart STEM programs that integrate teacher professional development, digital infrastructure, environmental data resources, laboratories, and transnational school partnerships, with a focus on underserved communities.
2. Professional-learning networks and open, culturally sensitive climate-STEM materials be established by teacher-education institutions and international education organisations. These programs will assist educators in creating cross-border learning opportunities, virtual labs, multidisciplinary projects, and climate-data research.
3. By creating climate/STEM laboratories, forming reciprocal international partnerships, integrating regional climate issues into STEM curricula, and assessing students using real project-based evaluation, schools, colleges, and universities should institutionalise climate-smart transnational STEM projects.

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Correlation Between Teachers' Pedagogical Knowledge of Multi-Media and Instructional Technology Teaching: A Case Study of Federal University of Education Zaria, Kaduna State

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Abstract

This paper examined Assessment of Teachers' Knowledge of ICT (Multi-Media Approach) in teaching Instructional Technology in Federal University of Education Zaria, Kaduna State-Nigeria. The study adopted a correlational survey design. The study population comprised forty-three (43) lecturers. Due to the manageable size of the population, all the 43 lecturers were included in the study using a census sampling technique. The instrument for data collection was a structured questionnaire and Observation Checklist/Scale for Effective Teaching of Instructional Technology. Reliability of the instrument was established using Cronbach Alpha, yielding a coefficient of 0.792. Descriptive statistics of mean scores and standard deviation were used to answer research questions while inferential statistics of Spearman Correlation was used to test the study hypotheses at 0.05 level of significance. The findings of this study reveals that there is a significant positive relationship between teachers' pedagogical knowledge of ICT and effective teaching of instructional technology ($r = 0.712$, $p < 0.05$). The findings also reveals that there is a strong significant positive relationship between teachers' content knowledge and ICT integration and effective teaching of instructional technology ($r = 0.763$, $p < 0.05$). Based on the findings, it was recommended among others that: Universities should prioritize continuous professional development that focuses on both pedagogical knowledge of ICT and content-specific integration.

Keywords: Teacher knowledge, ICT, Effective teaching of instructional technology.

Introduction

Knowledge acquisition is considered the basic level of ICT competencies which manifest in the ability to use technologies as a supplement to classroom practice while enhancing users' technological competencies (UNESCO, 2018). The shift from a view of Information Communication Technology (ICT) as a special activity where teachers have no control over to the one where teachers view ICT as a tool for teaching and learning is gaining currency globally. The focus of integrating ICT in education has increasingly become an important concern in education not only in developed countries but in developing countries as well (Anna & Bilatam, 2020). The task of teaching and research according to Adeyanju and Gbenga (2022) has received a boost essentially because information and

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communication technology get deployed to teaching. The realisation that ICT is the new normal reflects in the programmes of pre – service and in - service teachers who tend to motivate the self and get acquaint with the tool that helps in meeting the set goal of teaching and instructional delivery with minimal stress. Most tasks of teaching are now accomplished through the use of visual, audio, audio visual, real objects and contrive materials because they appeal to the senses of sight, hearing and touch. In addition, teachers are also becoming familiar with the rudiment of designing which is an activity based process of teaching and learning with consideration to an enriched environment. The term ICT integration in education generally refers to a technology-based approach to teaching and learning in which teachers use technology to facilitate learning in the classroom (Tshewang, 2019).

Multimedia approach is an interactive computer system that combines two or more media, including pictures, text, sound, and integrated animation, in a computer application (Jiang, 2022). Utilising this computer medium help teachers present more diverse learning contents, facilitate the interaction between students and the medium, and lay a solid foundation of professional knowledge, thereby optimising the teaching and learning environment and enhancing the educational quality. Teachers, as the architects of knowledge dissemination, find themselves at the forefront of this technological transformation, where their knowledge and proficiency in various aspects of ICT play a pivotal role in shaping the learning experiences of the next generation (Kumari & Srivastava, 2023). As the foundation of any technological endeavor, teachers are expected to possess basic computer skills that extend beyond mere familiarity with hardware and operating systems. Proficiency in utilizing common software applications, ranging from word processors to spreadsheet tools, forms the bedrock of their digital expertise. A teacher's ability to discern reliable online resources and curate relevant content is vital in providing students with accurate and up-to-date information. Moreover, digital communication skills, including email etiquette and collaboration tools, empowers teachers to foster effective communication channels within and beyond the classroom. Educational software has emerged as a powerful ally in the pedagogical arsenal, offering diverse tools for interactive and engaging learning experiences. Teachers with knowledge of such software can tailor their lesson plans to incorporate dynamic multimedia content, simulations, and gamified elements, thereby catering to varied learning styles and enhancing student engagement (Bhattacharjee, & Deb, 2016). Besides this, understanding the advantages that ICT brought in the traditional educational system will helps in increasing the demand for ICTs. Teachers equipped with the know-how of ICT tools can deliver dynamic presentations, annotate content in real-time, and create an immersive learning environment. Multimedia approach in teaching enhances the mastering of vital skills of a student by proper practice and drilling. It has also helped in providing solutions to problems by the use of learning how to do it yourself and the understanding of abstract concepts (Dominic-Ugwu & Nonyelum, 2019). Multimedia integration into teaching not only captivates students' attention but also facilitates a deeper understanding of complex concepts. Pedagogical knowledge is an in-depth understanding of teaching processes as emphasized by Luhamya, Bakkabulindi, and Muyinda (2017) such as lesson planning, classroom management, and evaluation are more effective with ICT integration. Teachers with deep pedagogical knowledge are more likely to design ICT-supported lessons that align with students' learning needs and cognitive levels. Akturk and Ozturk (2019), who reported that teachers who exhibited solid knowledge in both Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) dimensions are better adept at applying digital tools to teaching contexts.

Statement of the Problem

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The integration of Information and Communication Technology (ICT) in teaching has become a crucial aspect of modern education, particularly in higher learning institutions. However, despite the increasing adoption of ICT tools in classrooms, the effective integration of these technologies remains a challenge. In the context of Department of Curriculum and Instruction, Federal University of Education, Zaria there is limited understanding of how teachers' pedagogical knowledge of ICT and their content-specific ICT integration skills influence their ability to deliver effective technology-enhanced instruction. Pedagogical knowledge refers to a teacher's understanding of how to integrate ICT into their teaching methods, while content knowledge involves the teacher's expertise in their subject matter combined with the strategic use of ICT to facilitate learning. There is a need to assess how these two components contribute to the overall effectiveness of instructional technology in the university setting, ensuring that educators are equipped with the necessary skills to enhance student learning outcomes. The problem further extends to understanding the specific relationships between these areas of teacher knowledge and their impact on the quality of ICT integration in teaching practices. While research globally suggests that both pedagogical knowledge and content knowledge are essential for effective technology integration, there is a gap in understanding how these factors interact in the context of the Federal University of Education, Zaria. This study aims to address this gap by examining the relationship between teachers' pedagogical knowledge of ICT and effective teaching, as well as the relationship between content knowledge of ICT integration and instructional effectiveness.

Objectives of the Study

The specific objectives of the study are to:

1. assess the relationship between teachers' pedagogical knowledge of ICT and effective teaching of instructional technology in Department of Curriculum and Instruction, Federal University of Education, Zaria.
2. ascertain the relationship between teachers' content knowledge of ICT integration and effective teaching of instructional technology in Department of Curriculum and Instruction, Federal University of Education, Zaria.

Research Questions

The following questions were answered:

1. What is the relationship between teachers' pedagogical knowledge of ICT and effective teaching of instructional technology in Department of Curriculum and Instruction, Federal University of Education, Zaria?
2. What is the relationship between teachers' content knowledge of ICT integration and effective teaching of instructional technology in Department of Curriculum and Instruction, Federal University of Education, Zaria?

Hypotheses

The following hypotheses were tested at 0.05 level of significance:

1. There is no significant relationship between teachers' pedagogical knowledge of ICT and effective teaching of instructional technology in Department of Curriculum and Instruction, Federal University of Education, Zaria.
2. There is no significant relationship between teachers' content knowledge of ICT integration and effective teaching of instructional technology in Department of Curriculum and Instruction, Federal University of Education, Zaria.

Research Methodology

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This study adopted a correlational survey design. The study population comprised forty-three (43) lecturers from the Federal University of Education, Zaria. Due to the manageable size of the population, all 43 lecturers were included in the study using a census sampling technique.

The instrument for data collection was a structured questionnaire and Observation Checklist/Scale for Effective Teaching of Instructional Technology. Both questionnaire and checklist comprises of ten (10) items. The instrument was subjected to expert validation by senior lecturers in the Faculty of Education, Curriculum and Instruction Department, Federal University of Education, Zaria. Their suggestions and corrections were reviewed, harmonised, and incorporated to improve the clarity and relevance of the items. Reliability of the instrument was established using Cronbach Alpha, yielding a coefficient of 0.792, indicating high internal consistency. Descriptive statistics of mean scores and standard deviation were used to answer research questions while inferential statistics of Spearman Correlation was used to test the study hypotheses at 0.05 level of significance.

Presentation of Results

Research Question One: What is the relationship between teachers' pedagogical knowledge of ICT and effective teaching of instructional technology in Department of Curriculum and Instruction, Federal University of Education, Zaria?

Table 1: Mean and Standard Deviation scores of the respondents on Pedagogical Knowledge of ICT and Effective Teaching of Instructional Technology

Variable	N	Mean	Std. Dev.
Pedagogical Knowledge of ICT	43	4.40	0.40
Effective Teaching of Instructional Technology	43	3.15	0.55

Table 1 revealed that the mean score for Pedagogical Knowledge of ICT is 4.40, indicating that lecturers at Department of Curriculum and Instruction, Federal University of Education, Zaria generally have a strong pedagogical understanding of ICT. The mean score for Effective Teaching of Instructional Technology is 3.15, suggesting that lecturers' integration of instructional technology, although notable, is somewhat lower in comparison to their pedagogical knowledge of ICT.

Research Question Two: What is the relationship between teachers' content knowledge of ICT integration and effective teaching of instructional technology in Department of Curriculum and Instruction, Federal University of Education, Zaria?

Table 2: Mean and Standard Deviation scores of the respondents on Content Knowledge of ICT Integration and Effective Teaching of Instructional Technology

Variable	N	Mean	Std. Dev.
Content Knowledge of ICT Integration	43	4.48	0.38
Effective Teaching of Instructional Technology	43	3.20	0.58

Table 2 revealed that the mean score for Content Knowledge of ICT Integration is 4.48, showing a strong integration of content knowledge with ICT tools by the lecturers. The mean score for Effective Teaching of Instructional Technology is 3.20, indicating that there is a relatively moderate level of effective teaching, though there is still room for improvement in the use of ICT to its full potential in teaching.

Hypothesis One: There is no significant relationship between teachers' pedagogical knowledge of ICT and effective teaching of instructional technology in Department of Curriculum and Instruction, Federal University of Education, Zaria.

Table 3: Spearman Correlation on Pedagogical Knowledge of ICT and Effective Teaching

		Pedagogical Knowledge	Effective Teaching
Pedagogical Knowledge	Pearson Correlation	1	.712**
	Sig. (2-tailed)		.000

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	N	43	43
Effective Teaching	Pearson Correlation	.712**	1
	Sig. (2-tailed)	.000	
	N	43	43

Table 3 revealed that the Spearman correlation coefficient of 0.712 ($p < 0.05$) indicates a strong positive relationship between teachers' pedagogical knowledge of ICT and their effective teaching of instructional technology. Since $p < 0.05$, we reject the null hypothesis, concluding that teachers' pedagogical knowledge of ICT is significantly related to effective teaching.

Hypothesis Two: There is no significant relationship between teachers' content knowledge of ICT integration and effective teaching of instructional technology in Department of Curriculum and Instruction, Federal University of Education, Zaria.

Table 4: Spearman Correlation on Content Knowledge of ICT Integration and Effective Teaching

		Content Knowledge	Effective Teaching
	Pearson Correlation	1	.763 **
Content Knowledge	Sig. (2-tailed)		.000
	N	43	43
Effective Teaching	Pearson Correlation	.763 **	1
	Sig. (2-tailed)	.000	
	N	43	43

Table 4 revealed that the Spearman correlation coefficient of 0.763 ($p < 0.05$) shows a strong positive relationship between content knowledge and ICT integration and effective teaching. Since $p < 0.05$, we reject the null hypothesis, confirming that teachers' content knowledge of ICT integration are significantly related to effective teaching.

Discussion of Findings

The finding of this study revealed that there is a significant positive relationship between teachers' pedagogical knowledge of ICT and effective teaching of instructional technology ($r = 0.712$, $p < 0.05$). This finding agrees with that of Luhamya, Bakkabulindi, and Muyinda (2017) who emphasized that pedagogical knowledge is an in-depth understanding of teaching processes such as lesson planning, classroom management, and evaluation are more effective with ICT integration. Teachers with deep pedagogical knowledge are more likely to design ICT-supported lessons that align with students' learning needs and cognitive levels. The finding also revealed that there is a strong significant positive relationship between teachers' content knowledge and ICT integration and effective teaching of instructional technology ($r = 0.763$, $p < 0.05$). This finding corroborates with that of Akturk and Ozturk (2019), who reported that teachers who exhibited solid knowledge in both Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) dimensions are better adept at applying digital tools to teaching contexts.

Conclusion

The study reveals that both pedagogical knowledge of ICT and content knowledge with ICT integration are strongly linked to effective teaching of instructional technology. Specifically, content knowledge with ICT integration demonstrates stronger relationship than pedagogical knowledge emphasizing the critical role of both deep subject understanding and effective ICT integration in improving teaching outcomes.

Recommendations

Based on the findings of this study, it is recommended that:

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1. Universities should prioritize continuous professional development that focuses on both pedagogical knowledge of ICT and content-specific integration.
2. Workshops, seminars, and online courses should be designed to boost teachers' abilities to integrate ICT tools effectively, aligning with pedagogical strategies to improve content delivery.

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Comparative Effects of Concept Mapping and Problem-Solving Strategies On Geometry Performance among Upper Basic Students in Kano State, Nigeria

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Abstract

This quasi-experimental study investigated the "Influence of Concept Mapping and Problem-Solving Strategies on Geometry Performance of Upper Basic Students in Kano, exploring the potential of these strategies to enhance entrepreneurial innovation and skills, contributing to poverty reduction initiatives in Nigeria. Samples of 367 out of the population of 999,486 students from 1,001 public Upper Basic Schools were used. The experimental group 1 was exposed to Concept mapping, experimental group 2 to Problem solving and Control group was exposed to Conventional method respectively. Three research questions were raised and three null hypotheses were formulated to guide the study. The researcher developed an instrument, Geometry Performance Test (GPT) which was designed to test the performance after treatment in four areas of Geometry; angles, triangles, polygons and circles. Result of the t-test statistics revealed significant difference between the performances of the three groups. Findings from the study underscore the importance of innovative pedagogies in enhancing mathematical skills, promoting an entrepreneurial mindset, and ultimately addressing socio-economic challenges. Recommendations proffered based on the findings, includes; integrating the use of concept mapping in the teaching of geometry among Upper Basic Students so as to enhance students' performance, Mathematics teachers be sent on in-house trainings, workshops and seminars where modern teaching strategies are discussed such as MAN, STAN Conferences among others. Teachers' welfare should be improved to meet life challenges and teacher education at all levels should be carefully managed to incorporate all socio-cultural, environmental, economic and political aspects of life for the teachers.

Keywords: Concept Mapping, Problem-Solving Strategies, Geometry Performance,

Introduction

Mathematics is recognized globally as a key tool for national development. Geometry, as a branch of mathematics, develops spatial reasoning, logical thinking, and problem-solving skills essential for technical and vocational occupations (Clements & Battisa, 1992). In Nigeria, Upper Basic students' poor performance in geometry continues to limit their ability to acquire practical skills needed for self-employment. Concept Mapping and Problem Solving Strategies have been identified as learner-centered approaches that can enhance understanding and retention in mathematics (Novak &

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Gowin, 1984; Danjuma & Bajon, 2022). Beyond academic achievement, improved geometry performance has direct implications for Entrepreneurial Innovation in areas such as construction, tailoring, furniture making, and surveying; vocations that can drive poverty reduction in Kano State (Becker, 1993). Despite curriculum reforms, students in Kano State still perform poorly in geometry. Wanlor, Dalong, & Falade (2023) reported that "only 34% of upper basic students demonstrated competence in geometry" in Plateau State, a trend mirrored in Kano. In Kano State, failure in Mathematics in the Placement Examinations is very common. It was noticed that the performance in Mathematics at this level normally falls between 30-35% (KERC, 2024). Students' attempts in answering the Geometry sections of the yearly questions papers depict the need to undertake this study. This unfortunate development trail the student to Senior Secondary School Class thereby causing the students to perform poorly in Senior School Examinations. Records of the students' performance in Mathematics at the Upper Basic Placement Exams for 5 years (2020 – 2024) in Kano State revealed the need for the study. Traditional lecture methods have failed to connect classroom geometry to real-life applications (Shu'iabu & Sidi, 2020).

Geometry is foundational to many entrepreneurial activities in Kano; from architectural drawing to fashion design. The Sustainable Livelihoods Framework argues that education that builds practical skills reduces vulnerability and promotes income generation (Chambers & Conway, 1992). Therefore, improving geometry performance through innovative strategies like concept mapping and problem solving could translate to entrepreneurial skills and poverty reduction. Upper Basic students in Kano, Nigeria continue to exhibit poor performance in geometry (Wanlor et al., 2023). This poor foundation limits their capacity to engage in geometry-related vocations that are critical for entrepreneurial innovation. Consequently, many youths remain unemployed or underemployed, thereby perpetuating poverty in the state. The purpose of this study is to investigate the influence of Concept Mapping and Problem-Solving Strategies on Geometry Performance of Upper Basic Students in Kano, Nigeria and to examine the implications of improved geometry performance for entrepreneurial innovation and poverty reduction. Specifically, the study seeks to determine whether these instructional strategies can equip students with the mathematical competence needed to engage in self-reliant, income-generating activities, thereby contributing to poverty reduction in line with Sustainable Development Goal number 1: "No Poverty" (UNDP, 2015).

Objectives of the Study

The objectives of the study were to:

1. Investigate the influence of Concept Mapping Strategy on geometry performance of Upper Basic students in Kano, Nigeria.
2. Examine the influence of Problem-Solving Strategy on geometry performance of Upper Basic students in Kano, Nigeria.
3. Find out the differences between the Concept Mapping Strategy and Problem-Solving method on Upper Basic Students' Performance in Geometry.

Research Questions

In line with the objectives of the study, the following research questions guided this study:

1. What is the effect of Concept Mapping Strategy on geometry performance of Upper Basic students in Kano, Nigeria?
2. What is the effect of Problem-Solving Strategy on geometry performance of Upper Basic students in Kano, Nigeria?

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3. What is the difference between Concept Mapping Strategy and Problem-Solving method on the Geometry Performance of Upper Basic Students in Kano, Nigeria?

Null Hypotheses

Based on the research questions, the following null hypotheses were formulated and tested at α = 0.05 level of significance

Ho_1: There is no significant difference between the mean performance scores of the students exposed to Concept Mapping and those exposed to conventional method.

Ho_2: There is no significant difference between the mean performance scores of the students exposed to Problem Solving and those exposed to conventional method.

Ho_3: There is no significant difference between the mean performance scores of the students exposed to Concept Mapping and those exposed to Problem Solving.

Theoretical Framework for the Study

This study is anchored on multiple interrelated theories drawn from educational psychology, Entrepreneurship and development economics. The central premise is that the use of Concept Mapping and Problem-Solving Strategies can improve Geometry Performance of Upper Basic students and that this improvement has direct implications for Entrepreneurial Innovation and Poverty Reduction. The following theories provide the conceptual foundation for this study. Ausubel's Theory of Meaningful Learning (1968) provides the basis for concept mapping. Ausubel asserted that "the most important single factor influencing learning is what the learner already knows. According to this theory, learning is meaningful when new information is consciously and explicitly linked to relevant concepts already in the learner's cognitive structure. Novak and Cañas (2008) extended this idea by developing concept mapping as a graphical tool for "organizing and representing knowledge; they facilitate meaningful learning". In the context of geometry, concept mapping enables Upper Basic students in Kano to visually connect theorems, properties, and constructions. This aligns with the Van Hiele Theory of Geometric Thought (1986), which proposes that learners progress through five levels of geometric understanding, from visualization to rigor. Concept mapping helps students move from concrete visualization to abstract reasoning, a skill essential for technical fields. Another study which is grounded in Polya's Problem Solving Theory (1945), described problem solving as "a practical art, like swimming; you learn by doing". He proposed four stages: *understanding the problem, devising a plan, carrying out the plan and looking back*. This systematic approach mirrors the process entrepreneurs use to identify market gaps, design solutions, and evaluate outcomes. Similarly, Vygotsky's Social Constructivism Theory (1978) supports collaborative problem solving. Vygotsky argued that "what a child can do in cooperation today, he can do alone tomorrow". When students engage in group problem solving and brainstorming in geometry, they operate within the Zone of Proximal Development, building both mathematical competence and teamwork skills required in cooperative businesses. Moreover, Bandura's Social Cognitive Theory (1986) explains the motivational dimension. It stated that "people's level of motivation, affective states, and actions are based more on what they believe than on what is objectively true". As students experience success in geometry through concept mapping and problem solving, their self-efficacy increases. Higher self-efficacy in mathematics has been linked to greater interest in STEM careers and entrepreneurial ventures. This is critical where youth need confidence to start small enterprises in construction, fashion design, furniture making and surveying; all of which require geometric knowledge.

The link between improved geometry performance and economic outcomes is explained by Human Capital Theory (Becker, 1993) and Schumpeter's Theory of Entrepreneurial Innovation (1934).

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Becker emphasized that "education and training are the most important investments in human capital". When Upper Basic students master geometry, they acquire technical human capital that can be converted into productive skills. Schumpeter (1934) further argued that "the function of entrepreneurs is to reform or revolutionize the pattern of production; by exploiting an invention". Geometry provides the basis for innovation in product design, efficient use of materials and spatial planning. For example, a student who understands area, volume and angles can innovate in block moulding, tailoring patterns or architectural drawings; creating new businesses and jobs. Furthermore, Freire's Pedagogy of the Oppressed (1970) supports the use of problem-posing approaches in mathematics. Freire (1970) contrasted "banking education" with "problem-posing education" which "affirms men and women as beings in the process of becoming". By engaging students with real-life geometric problems; such as drainage, housing layout and land measurement, problem solving makes mathematics relevant and empowering. This empowerment orientation is essential for addressing local development challenges. Finally, the ultimate outcome of this study is situated within the Sustainable Livelihoods Framework (Chambers & Conway, 1992). Chambers and Conway (1992) defined a sustainable livelihood as one that "can cope with and recover from stress and shocks, while not undermining the natural resource base". In this framework, education and skills are key human assets. Improved geometry performance, driven by effective instructional strategies, strengthens students' human assets, enabling them to pursue self-employment and technical vocations. This reduces dependence and contributes to poverty reduction at household and community levels.

Review of Empirical Studies

Several empirical studies conducted have examined the influence of concept mapping, problem solving and related instructional strategies on students' performance in mathematics, with particular emphasis on geometry. The findings from these studies provide strong justification for investigating the influence of these strategies among Upper Basic students in Kano State and their implications for entrepreneurial innovation and poverty reduction. Shu'iabu and Sidi (2020) investigated the effects of problem-solving instructional strategy on students' academic achievement in geometry among 201 SSII students in Gwale Local Government Area, Kano State. Using a pretest, post-test quasi-experimental design and the Geometric Achievement Test with reliability of 0.95, the study found that problem solving strategy significantly improved students' academic achievement in geometry compared to conventional methods. Similarly, Mamman and Surajo (2021) examined the effect of GeoGebra software on students' attitude and achievement in circle geometry at Kano University of Science and Technology. Their findings revealed that students taught with GeoGebra outperformed those taught with traditional methods and also developed more positive attitudes toward circle geometry. These two studies suggest that active, technology-enhanced and problem-based approaches can address geometry learning challenges. Research finding by Danjuma and Bajon (2022) who, in a quasi-experimental study of 60 Upper Basic students in Taraba State, reported that concept mapping had a significant effect on students' academic performance in basic science, $t = 3.63$, $p = 0.00$. Danjuma and Bajon (2022) concluded that "concept mapping strategy improves students' performance in basic science". Although the subject was basic science, the study was conducted at Upper Basic level, which is directly relevant to the present study.

The need for improved instructional strategies in geometry is further highlighted by studies that revealed low proficiency among Upper Basic students. Wanlor, Dalong, and Falade (2023) assessed the geometry proficiency of 393 Upper Basic Education students in Plateau State. They found that only 34% of the students passed overall geometry, while 36% passed geometric construction. The

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researchers concluded that "the examinees lacked proficiency in solving problems involving geometric constructions". This low performance calls for innovative teaching methods such as concept mapping and problem solving. In response, Mustapha, Ibrahim and Danjuma (2025) developed and calibrated a geometry diagnostic test for 20,550 Universal Basic Education 3 students in Plateau Central. They recommended that "UBE mathematics teachers should make adequate use of diagnostic tests in teaching geometry" to identify learning gaps and improve performance. Other studies have explored related cognitive and collaborative strategies that support geometry learning. Usman and Musa (2023) found in Borno State that teaching prior knowledge of basic geometric and mensuration concepts significantly improved learners' general cognitive outcomes and performance in geometry. This supports the use of concept mapping, which activates prior knowledge. Owolabi and Eze (2023) investigated brainstorming learning strategy in Nigeria using a Geometry Performance Test covering angles, triangles, polygons, and mensuration from the Upper Basic 8 curriculum. With instrument reliability of 0.83, they found that students taught with brainstorming outperformed those taught with teacher-led instruction. The authors emphasized that brainstorming "emphasizes teamwork and group discussions for problem-solving" (Owolabi & Eze, 2023). This aligns with Aliyu and Sani (2023) who, in Katsina State, found that concept mapping promotes cooperative learning as "in mind mapping and concept mapping students form themselves as cooperative groups". Although their study was in geography, the pedagogical implication for mathematics is clear. These findings collectively provide a comprehensive framework for understanding the influence of Concept Mapping and Problem-Solving Strategies on Geometry Performance of Upper Basic Students and exploring the potential of these strategies to enhance entrepreneurial innovation and skills, contributing to poverty reduction initiatives in Nigeria.

Research Methodology

The research adopted Quasi-experimental design. The population of the study was 999,486 students from 1,001 public upper basic schools in Kano State. A total sample of 367 students of males and females was selected using multiple sampling techniques of Cluster, Stratified and simple Random Sampling. Two (2) Education Zones were selected out of the twenty (20) zones. Thereafter stratified sampling technique was used to select types of schools in which two were drawn each. Intact upper basic 3 classes were finally chosen in the schools selected as the sample of the study in order not to disrupt the school normal activities. Six Schools were drawn with total number of students being 367, which formed the study groups. A total of three (3) research questions were answered with the descriptive statistics, while the 3 null hypotheses were tested using inferential of Independent t test statistics at 0.05 alpha level of significance.

Table 1 Study Groups

Groups	Male	Female	Total	Percent %
Exp Group1 Concept Mapping	59	61	120	32.7
Exp Group 2 Problem solving	61	63	124	33.8
Control Group Conventional	57	66	123	33.5
Total	177	190	367	100.0

Source: Field data

Table **1** showed the three study groups. The first experimental Group 1 (EG1) students exposed to the concept mapping were 120 representing 32.7% of the sample while 124 representing 33.8% of the were experimental Group 2 (EG2) exposed to the problem solving method and the third study group was the control Group comprising of 123 or 33.5% received the conventional lecture method. The experimental group 1 (EG1) was exposed to geometry instruction through Concept Mapping Model of Instruction and the experimental group 2 (EG2) was exposed to geometry instruction

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through Problem Solving method of Instruction, while the control group (CG) received the geometry instructions through conventional/lecture method. There are many types of concept mapping, but the researcher decided to use Hierarchy Concept Mapping for the fact that it is simple to construct and presents information in a descending order of importance. Polya's Problem Solving Approach was use for the experimental group 2 (EG2). The teaching activities involved the regular mathematics teacher in the schools selected, after thorough discussion and briefing with the researcher to avoid teacher influence and minimize "teacher difference" and experimental bias. The teaching covers 4 units in the topic area (Plane Geometry), six weeks (2- period per week) were used for the whole of the exercise. The unit topics covered from Geometry includes; (i) Plane shape (quadrilaterals): different properties of Parallelogram, Rhombus and Kite. (ii) Connections between quadrilaterals. (iii) Angles between lines with identification of the Straight lines, angles, vertically opposite angles, Corresponding angles and Alternate angles. (iv) Angles in a triangle, types of angles; Equilateral, Isosceles, Scalene, Right angles and calculating the different sizes of angles. (v) Angles in a quadrilaterals and calculation of angles in quadrilaterals. (vi) Polygons, type of polygons, finding the interior angles of polygon. The justification for this selection remained with the facts that they are contained in upper basic school curriculum. These topics also frequently appear in the upper basic placement examinations. The instruments used for this research was "Geometry Performance Test (GPT) for post-test." The Geometry Performance Test (GPT) with reliability index of 0.83 was designed to measure the students' performance after the experiment to all groups. The test consisted of 50 multiple choice questions and was developed from the past upper basic Placement Exams and from the New General Mathematics for West Africa. The test also carries equal marks of 2 with a total of 100% marks. The data collected from the Geometry Performance Test (GPT) was tested using independent t-test, inferential statistics at α=0.05 level of significance for three (3) hypotheses.

Presentation of Results

Hypotheses Testing

Hypothesis one: There is no significant difference between the mean performance scores of the students exposed to Concept Mapping and those exposed to conventional method.

Table 2: Independent t test statistics on difference between the mean performance scores of the students exposed to Concept mapping and those exposed to conventional method

GROUPS	N	Mean	STD	Mean Differ.	Df	t computed	t critical	P-val
Concept Mapping (Exp1)	120	52.11	15.46	3.77	241	2.17	1.96	0.03
Conventional (Control)	123	48.34	11.20					

P = 0.030 < 0.05, t computed = 2.178 > 1.96 t-crit at df 241

According to the independent t test statistics from table 2, significant difference exist between the mean performance scores of the students exposed to Concept mapping and those exposed to conventional method. Reasons being that the p-calculated value of 0.03 is below the 0.05 alpha level of significance and the computed t value of 2.17 is higher than the 1.96 t-critical at df 241. Their mean performances are 52.11 and 48.34 for students exposed to Concept mapping and those exposed to conventional method respectively. The mean performance difference of 3.77 is in favour of those students exposed to concept mapping. Therefore, the null hypothesis which states that there is no significant difference between the mean performance scores of the students exposed to Concept mapping and those exposed to conventional method is hereby rejected.

Hypothesis Two: There is no significant difference between the mean performance scores of the students exposed to Problem Solving and those exposed to conventional method

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Table 3: Independent t test statistics on difference between the mean performance scores of the students exposed to Problem Solving and those exposed to conventional method

GROUPS	N	Mean	STD	Mean Differ.	Df	t computed	t critical	P-val
Problem Solving (Exp2)	124	51.25	13.81	2.91	245	2.11	1.96	0.04
Conventional (Control)	123	48.34	11.20					

P = 0.07 > 0.05, t computed = 2.11 > 1.96 t-crit at df 245

From the table 3 of Independent t test statistic, it was surmised that there is significant difference between the mean performance scores of the students exposed to Problem Solving and those exposed to conventional method. Reasons being that the p calculated value of 0.04 is less than the 0.05 alpha level of significance and the computed t-value of 2.11 is above the 1.96 t-critical at df 245. Their mean performances are 51.25 and 48.34 for students exposed to Problem Solving and those exposed to conventional method, respectively with a mean performance difference of 2.91 in favour of those students exposed to Problem Solving. Therefore the null hypothesis which stated that, there is no significant difference between the mean performance scores of the students exposed to Problem Solving and those exposed to conventional method is hereby dis-confirmed.

Hypothesis Three: There is no significant difference between the mean performance scores of the students exposed to Concept mapping and those exposed to Problem Solving

Table 4: Independent t test statistics on difference between the mean performance scores of the students exposed Concept mapping and those exposed to Problem Solving Strategy

GROUPS	N	Mean	STD	Mean Differ.	Df	t computed	t critic	P-val
Concept Mapping (Exp1	120	52.11	15.46	0.86	242	0.45	1.96	0.64
Problem solving (Exp2)	124	51.25	13.81					

P = 0.648 > 0.05, t computed = 0.45 < 1.96 t-crit at df 242

From table 4 of the Independent t test statistic, it was surmised that there is no significant difference between the mean performance scores of the students exposed to Concept mapping and those exposed to Problem Solving strategy. Reasons being that the p calculated value of 0.64 is greater than the 0.05 alpha level of significance and the computed t-value of 0.45 is below the 1.96 t critical at df 242. Their mean performances are 52.11 and 51.25 for students exposed to Concept mapping and those exposed to Problem Solving respectively with a mean performance difference of only 0.86 in favour of those students exposed to Concept mapping, but this difference is statistically not significant. Therefore, the null hypothesis which stated that there is no significant difference between the mean performance scores of the students exposed to Concept mapping and those exposed to Problem Solving, is hereby accepted and retained.

Summary of Findings

Based on the analysis, the study found that:

1. There is a significant difference in Geometry performance between students taught with Concept Mapping Strategy and those taught with Conventional method, in favor of Concept Mapping.
2. There is a significant difference in Geometry performance between students taught with Problem Solving Strategy and those taught with Conventional method, in favor of Problem Solving.

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3. There is no significant difference in Geometry performance between students taught with Concept Mapping Strategy and those taught with Problem Solving Strategy.

Discussion of Findings

The findings of this study revealed that both Concept Mapping and Problem Solving Strategies significantly influenced the Geometry performance of Upper Basic students in Kano, Nigeria when compared with the Conventional method. The independent t-test results showed a statistically significant difference in mean performance scores between students taught with Concept Mapping 'M = 52.11' and those taught with Conventional method 'M = 48.34', t (241) = 2.17, p = 0.03. Similarly, students exposed to Problem Solving Strategy 'M = 51.25' performed significantly better than those in the Conventional group 'M = 48.34', t (245) = 2.11, p = 0.04. However, there was no statistically significant difference between Concept Mapping 'M = 52.11' and Problem Solving 'M = 51.25' groups, t (242) = 0.45, p = 0.64. The finding from the study align with Shu'iabu and Sidi (2020), who investigated the effects of problem solving instructional strategy on students' academic achievement in geometry among 201 SSII students in Gwale Local Government Area, the study found that problem solving strategy significantly improved students' academic achievement in geometry compared to conventional methods. The results also align with research finding by Danjuma and Bajon (2022) who, in a quasi-experimental study of 60 Upper Basic students in Taraba State, reported that concept mapping had a significant effect on students' academic performance in basic science. The findings from the study, is therefore strongly correlated to the earlier empirical frameworks which posited that learner-centered strategies such as Concept Mapping and Problem Solving enhance conceptual understanding, retention, and application of mathematical knowledge better than teacher-centered methods. The superior performance of the experimental groups suggests that when students are actively engaged in organizing knowledge and solving real-life problems, they develop critical thinking and innovation skills. This has direct implications for Entrepreneurial Innovation and Poverty Reduction, because improved Geometry performance builds the foundational STEM and spatial reasoning skills needed for technical vocations, design, construction, and entrepreneurship; key areas for self-reliance and economic empowerment in the 21st century.

Conclusion

The study concludes that Concept Mapping and Problem Solving Strategies are effective instructional approaches for improving Upper Basic students' performance in Geometry in Kano, Nigeria. Both strategies proved significantly better than the Conventional method, and either can be adopted by teachers to enhance learning outcomes. By strengthening students' mathematical and problem-solving competence, these strategies contribute to the development of human capital required for Entrepreneurial Innovation and ultimately for Poverty Reduction in line with 21st-century learning goals.

Recommendations

Based on the findings, the following recommendations are made to:

1. Teachers: Mathematics teachers at the Upper Basic level in Kano should adopt Concept Mapping and Problem-Solving Strategies in teaching Geometry to promote deeper understanding and application instead of relying solely on the Conventional lecture method.
2. Government and College of Education: Relevant authorities should organize workshops, seminars and in-service training for teachers on the effective use of Concept Mapping and Problem-Solving Strategies in the classroom.

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3. Curriculum Planners: The curriculum should emphasize activity-based and problem-centered learning in Geometry to equip students with practical and entrepreneurial skills that can reduce poverty and foster innovation.
4. Researchers: Further studies should be carried out to examine the long-term effects of these strategies on students' performance in other areas of Mathematics and Science.

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Effect of Revit Software on Academic Performance in Building Drawings among Colleges of Education Students in North-West, Nigeria

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Abstract

This study investigated the effect of Revit software on students' academic performance in Building Drawing in Colleges of Education in North-West Nigeria. The study was guided by two specific objectives, two research questions and two null hypotheses. A quasi-experimental research design, specifically the pretest-posttest non-equivalent control group design, was adopted. The study was conducted in Colleges of Education in North-West Nigeria. Two colleges of Education were selected using a simple random sampling technique the sample consisted of one experimental group with intact class of 25 students and one control group with an intact class of 21 students. Data were collected using the researcher developed Building Drawing Performance test questions (BLDDRWPTQ), consisting of two questions designed to measure students' performance practical skills. The instruments were pilot-tested using test-retest method, yield correlation coefficient of 0.876 and 0.717 respectively. The data were analyzed using means, standard deviations and independent sample-t-test. The findings revealed a statistically significant difference in the posttest mean academic performance scores of students exposed to Revit software and those taught using the conventional teaching methods. The finding underscores the potential of Revit software to enhance students' academic performance

Keywords: Revit software, Building Drawing, performance, Building information modelling (BIM)

Introduction

With the advancement of technology, digital tools such as Revit software have transformed the way building drawing is taught and learned. Revit is a Building Information Modelling (BIM) software that allows users to design, visualize, and simulate building structures in a three-dimensional environment. This interactive capability enhances students' understanding by providing realistic representations of building components. The level of awareness of Revit is becoming increasingly massive globally both in advanced countries and developing nations of the world Architecture, Engineering, and Construction (AEC) professionals are beginning to key into this new paradigm shift, which is becoming more versatile with steady technology improvements. The benefits are endless and new frontiers of the tool are being discovered. Autodesk (2020) defined Revit software as the

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holistic process of creating and managing information for a built asset through an intelligent model and enabled cloud platform that helps integrate structured multi-disciplinary data to produce a digital representation of an asset across its lifecycle. It's also a sustainable and integrated collaborative process that unites all project stakeholders through its digital information storage and editing systems to facilitate seamless design documentation, construction, and building operations for shared benefits of improved accuracy, productivity, communication, decision-making, waste reduction and efficiency of time, energy and water resources. Academic performance in building drawing is influenced by several factors, including teaching methods, instructional materials, and students' level of interest. Conventional teaching methods are often teacher-centered and may not adequately support active learning. As a result, students may experience difficulties in understanding concepts, leading to poor performance and low retention.

Statement of the Problem

With the advancement of technology, software such as Revit has been introduced as a modern tool for architectural design and building drawing. Revit offers features such as 3D modeling, visualization, and automation, which have the potential to enhance students' understanding and engagement. Despite these advantages, the integration of Revit software into teaching and learning in Colleges of Education, especially in North-West Nigeria, appears to be limited. Consequently, students continue to experience difficulties in grasping Building Drawing concepts effectively. Furthermore, there is a growing concern about students' declining Performance in building drawing course, which may be linked to the persistent use of conventional teaching methods.

Objective of the Study

The aim of this study was to determine the Effect of Revit software on Students' Performance in Building Drawing in Colleges of Education in North-West, Nigeria.

Specifically, the study seeks to:

1. Determine the difference between the pretest mean academic performance scores of Building Drawing students in experimental group and those in conventional group prior to the treatment.
2. Determine the difference between the posttest mean academic performance scores of students taught Building Drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North - West, Nigeria.

Research Questions

The following research questions were formulated to guide the study:

1. What is the difference between the pretest mean academic performance scores of Building Drawing students in experimental group and those in conventional group prior to the treatment?
2. What is the difference between the posttest mean academic performance scores of students taught Building Drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North – West Nigeria.

Hypotheses

The following null hypotheses were formulated for the study and tested at 0.05 level of significance.

H_{O1}: There is no significant difference between the pretest mean academic performance scores of students in experimental group and those in conventional group prior to the treatment?

H_{O2}: There is no significant difference between the posttest mean academic performance score of students taught Building Drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North-West Nigeria.

Scope of the Study

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This study focused on the effect of Revit software on students' academic performance in Building Drawing in Colleges of Education in North West Nigeria.

Literature Review

Students' performance is among the most important indicators used for evaluating instructional effectiveness within educational systems. In technical and vocational education, these variables are particularly significant because effective learning requires not only theoretical understanding but also practical competence, psychomotor development, visualization ability, creativity, and long-term application of acquired knowledge. Contemporary educational researchers emphasized that instructional technologies, teaching methods, learning environments, and students' engagement significantly influence learning outcomes within technical education (Dwivedi et al 2023, Petko 2025, ElSayary 2026, Gupta et al 2026). Performance refers to the measurable level of achievement attained by students after exposure to instructional activities. It is commonly evaluated through examinations, tests, assignments, practical tasks, projects, and other forms of academic assessment. Contemporary scholars argued that Performance reflects the extent to which students successfully acquire instructional content, practical competencies, and conceptual understanding within a given field of study (Bervell & Umar 2023, Oviawe et al 2021, Nikolopoulou et al 2021, Petko 2025). Within Building drawing education, students' Performance is closely associated with their ability to: interpret technical drawings, visualize structural relationships, produce accurate building designs, apply drafting principles and demonstrate practical modelling competence. Recent BIM education studies revealed that students exposed to technology-supported instructional systems such as Revit and BIM-based learning environments demonstrate significantly higher academic achievement than students taught using conventional drafting methods (Oyesode et al 2023, Agirbas 2020, Turk et al 2022, Bui et al 2023). Contemporary scholars further explained that digital instructional technologies improve students' understanding of abstract technical concepts through visualization, simulation, and practical interaction, thereby enhancing Performance. Students' Performance refers to learners' emotional engagement, enthusiasm, motivation, and willingness to participate actively in instructional activities. Recent educational technology studies revealed that interactive and learner-centered instructional systems significantly improve students' Performance in technical subjects because digital learning environments reduce instructional boredom and increase active participation (Nikolopoulou et al 2021, Bervell & Umar 2023, Turk et al 2022, Alenezi 2024). Within Building Drawing instruction, students frequently experience learning difficulties when instructional methods are excessively theoretical, abstract, or teacher-centered. Contemporary scholars argued that Revit-supported instructional systems improve students' Performance because learners are able to interact directly with realistic virtual building models, simulation environments, and collaborative design activities (Oyesode et al 2023, Sacks et al 2021, Bui et al 2023, Agirbas 2020). Despite the potential benefits associated with technology-supported instructional systems, several factors continue to affect students' performance within technical education programmes. Contemporary studies identified major influencing factors including: inadequate instructional facilities, poor ICT infrastructure, insufficient practical exposure, ineffective teaching methods, low technological competence, unstable electricity supply, and limited access to digital instructional resources (Akinradewo et al 2025, Bervell & Umar 2023, Oyesode et al 2023; Alenezi, 2024).

Research Methodology

Research Design

This study adopted a quasi-experimental non-equivalent control group design.

Area of the Study

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The study was conducted in North-West Nigeria.

Population of the Study

The population of the study comprised all 187 NCE III Building Technology Education students enrolled in the eight Colleges of Education offering Building Technology Education in North-West Nigeria.

Sample and Sampling Techniques

The sample for the study consisted of 46 NCE III Building Technology Education students from two sampled Colleges of Education in North-West Nigeria. The two Colleges of Education were purposively selected and the study used intact classes.

Table 1: Sample Colleges of Education

S/n	name of institution	state	location	funded by	no of students
1.	Isa Kaita College of Education	Katsina	Dutsin Ma	State Government	25
2.	Federal College of Education	Sokoto	Gidan madi	Federal Government	21
	TOTAL				**46**

Source: Field Survey, (2025)

Instrument for Data Collection

The Building Drawing Performance Test Questions (BLDDRWTQ) were developed by the researcher based on the NCCE 2020 minimum standards and the relevant course content of Building Technology Education.

Validation of the Instrument

The instruments used for the study was subjected to face and content validation to ensure its suitability and effectiveness in measuring what it was intended to measure.

Reliability of the Instrument

Test – retest method was used to determine the reliability of the instrument.

Method of Data Collection

The data for the study was collected by the researchers with the help of research assistants that were selected and trained for the purpose of the study form the sampled Colleges of Education.

Method of Data Analysis

The data collected were analyzed using Mean and Standard deviation to answer research questions. Mean was used to determine the average academic performance scores of students in both groups, while standard deviation were used to show the spread of the scores from the mean.

Presentation of Results

Research Question One

What is the difference between the pretest mean academic performance scores of Building Drawing students in experimental group and those in conventional group prior to the treatment?

A descriptive statistic was used to determine the difference in the pretest mean difference in academic performance scores of Building Drawing students in experimental group and those in conventional group prior to treatment. The results in table 1, Indicated that there was existence difference in mean academic performance of experimental group (M = 2.43, SD = 0.256) and conventional group (M = 2.33, SD = 0.718) at the pretest stage. This indicated that experimental group and conventional group are almost equal in their Building Drawing performance prior to treatment.

Table 1: Descriptive statistics of pretest mean performance scores of Building Drawing students in experimental group and those in conventional group prior to the treatment.

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Variable	Group	N	Mean	Std. Dev	MD
Pretest	Experimental	25	2.43	.256	
	Conventional	21	2.33	.718	
	Total	**46**			0.1

Note: N=Number of students, Std. Dev= Standard deviation.MD, Mean deference

Research Question Two

What is the difference between the posttest mean academic performance scores of Students taught Building Drawing using Revit software and those taught using conventional teaching method in colleges of Education in North-West Nigeria

A descriptive statistic was performed to find out the difference between mean academic performance Building drawing in experimental group and those in conventional group in Colleges of Education in North-West Nigeria. The results in Table 2, revealed that there was a difference in the posttest mean academic performance of experimental group (M = 4.22, SD = 0.265) and conventional group (M = 2.28, SD = 0.272). This indicated that experimental group have better performance scores than the counterpart in the conventional group.

Table 2: Descriptive statistics of posttest mean performance scores of Students taught Building Drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North-West Nigeria

Variable	Group Mean	N		Std. Dev	MD
Post-test	Experimental	25	4.22	.265	
	Conventional	21	2.28	.272	
	Total	**46**			1.94

Note: N=Number of students, Std. Dev= Standard deviation, MD=Mean difference

Hypotheses Testing

An independent samples t-test was used to test the null hypotheses at 0.05 level of significant.

Test of Null Hypothesis 1

H_{O1} There is no significant difference between the pretest mean academic performance scores of Building Drawing students in experimental group and those in conventional group prior to the treatment?

The outcome of Independent sample t–test in Table 3, Indicated that there is no existence of a statistically significant difference between the pretest mean academic performance scores of Building Drawing students in the experimental group (M = 2.43, SD = 0.256) and those in the conventional group (M = 2.33, SD = 0.718), t(24.276) = 0.628, P = .536. The Null Hypothesis one is therefore, accepted. This finding indicated that experimental group and conventional group come from the same population because at the start of the experiment they are equal statistically in terms of their academic performance in Building Drawing prior to the treatment?

Table 3: Independent samples t-test of pretest mean academic performance scores of Building Drawing students in experimental group and those in conventional group prior to the treatment?

			Levene's Test for Equality of Variances						
Variable	Groups	N	F	Sig.	t-value	Mean	Std. Dev	p-value	Decision
Pre-test	Experimental	25	36.452	.000	.628	2.43	.256	.536	Accepted
	Conventional	21				2.33	.718		

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Test of hypothesis 2

H_{O2} There is no significant difference between the posttest mean academic performance scores of students' taught Building Drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North-West Nigeria

The statistical evidence of Independence sample t-test presented in Table 4, Indicated that there was a statistically significant difference between the posttest mean academic performance scores of students in experimental group (M = 4.22, SD = 0.262) and those in the conventional group (m = 2.28, SD = 0.272), t(44) = 24.540,P < 0.01. Null Hypothesis two was therefore, not accepted. This finding indicated that Revit software had a significant effect on posttest academic performance on experimental group compared to conventional group.

Table 4: Independent samples t-test of posttest mean academic performance scores of students taught Building Drawing using Revit software and those taught using conventional teaching method in Colleges of Education in North-West Nigeria

		Levene's Test for Equality of Variances							
Variable	Groups	N	F	Sig.	t-value	Mean	Std. Dev	p-value	Decision
Post-test	Experimental	25	.118	.733	24.540	4.22	.265	.000	Rejected
	Conventional	21				2.28	.272		

Summary of Findings

Based on the analysis of the data collected, the following findings were made:

1. The finding of Research Question One revealed that there was a difference between the pretest mean academic performance scores of students in the experimental group and those in the conventional group before the commencement of the instructional intervention. Students in the experimental group obtained a marginally higher pretest mean score than those in the conventional group, indicating that both groups had comparable levels of prior knowledge in Building Drawing. This finding is supported by the corresponding Hypothesis One, which revealed that there was no statistically significant difference between the pretest mean academic performance scores of students in the experimental and conventional groups. This implies that both groups were statistically equivalent at the beginning of the experiment.
2. The finding of Research Question Two revealed that students taught Building Drawing using the Revit instructional approach achieved substantially higher posttest academic performance scores than students taught using the conventional instructional method. This indicates that the Revit instructional approach significantly improved students' academic performance in Building Drawing. The finding is supported by the corresponding Hypothesis Two, which revealed that there was a statistically significant difference between the posttest mean academic performance scores of students in the experimental and conventional groups in favour of the experimental group. This implies that Revit-based instruction was more effective than the conventional teaching method in enhancing students' academic performance

Conclusion

The study concluded that the use of Revit software as an instructional tool significantly improves students' academic performance in Building Drawing compared with the conventional teaching method. The integration of Revit software provides an interactive and practical learning environment

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that promotes better visualization, deeper understanding of building concepts, and improved problem-solving skills. Consequently, Revit software represents an effective instructional innovation capable of improving the quality of teaching and learning in Building Technology programmes in Colleges of Education. Its adoption will contribute to producing graduates with the digital competencies and professional skills required in the modern construction industry.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Colleges of Education should integrate Revit software into the teaching and learning of Building Drawing to enhance students' academic performance.
2. The Federal and State Governments should provide adequate Information and Communication Technology (ICT) facilities, including computer laboratories, multimedia projectors, stable electricity, and licensed Revit software, to support effective instructional delivery.

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Pedagogical Challenges in Nigerian Secondary School Mathematics Education: A Conceptual Examination of Causes, Consequences and Reform Strategies

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Abstract

Mathematics is fundamental to scientific literacy, technological development, economic productivity, and participation in Science, Technology, Engineering, and Mathematics (STEM). However, mathematics education in Nigerian secondary schools continues to face pedagogical challenges that constrain students' conceptual understanding, reasoning, problem-solving, engagement, and achievement. This conceptual paper examines major pedagogical challenges in Nigerian secondary school mathematics education and their implications for learning. Drawing on Constructivist Learning Theory, Social Cognitive Theory, and pedagogical content knowledge, the paper argues that persistent learning difficulties arise from interactions among teacher knowledge, instructional practices, assessment, curriculum demands, classroom conditions, and learners' prior knowledge. Major challenges include teacher-centred and procedural instruction, inadequate mathematical discourse and differentiation, examination-oriented assessment, limitations in teacher professional development, large classes and resource constraints, and weak integration of contextualized learning and problem-solving. Evidence from Nigerian studies indicates that alternative instructional approaches and teachers' professional competencies can contribute to improved mathematics learning. The paper proposes a conceptual framework linking structural conditions, teacher factors, pedagogical practices, learner experiences, and mathematics learning outcomes. It concludes that sustainable improvement requires conceptually focused, learner-centred, reflective, formative, and context-responsive pedagogy supported by continuous teacher professional development and appropriate educational resources.

Keywords: Mathematics education, Pedagogical challenges, Secondary schools, Pedagogical content knowledge

Introduction

Mathematics occupies a strategic position in secondary education because it develops knowledge and skills that support scientific reasoning, problem-solving, further education, and participation in a wide range of occupational fields (National Council of Teachers of Mathematics [NCTM], 2014; Organisation for Economic Co-operation and Development [OECD], 2023). It is also integral to Science, Technology, Engineering, and Mathematics (STEM) education and contributes to the quantitative and analytical competencies required to understand and address scientific, technological, occupational, and societal problems (OECD, 2023). Consequently, the quality of mathematics teaching has implications beyond examination performance, extending to learners' capacity to reason mathematically, solve problems, interpret quantitative information, and apply mathematical knowledge in different contexts (NCTM, 2014; OECD, 2023).

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Despite this importance, mathematics teaching and learning in Nigerian secondary schools continue to face challenges associated with instructional effectiveness and students' achievement (Akinpelu et al., 2024; Olumuyiwa & Akinsola, 2021). Nigerian studies have investigated learner-centred, collaborative, and interactive approaches as possible responses. Awofala and Agbolade (2024), for example, found significant effects of peer tutoring on mathematics achievement among senior secondary students in Lagos State. Similarly, Ahmad and Zakariyya (2022) reported that students taught bearings through collaborative problem-solving performed significantly better than those taught through conventional instruction. Such findings suggest that opportunities for participation, collaboration, exploration, and problem-solving can contribute positively to mathematics learning. However, they should not be interpreted as evidence that one instructional method is universally superior to another. Rather, they highlight the importance of the quality and appropriateness of pedagogical practices within particular classroom contexts.

Mathematics pedagogy is more complex than a choice between "traditional" and "modern" teaching methods. It involves what teachers know about mathematics and learners, how they represent mathematical ideas, how they assess understanding, how they respond to errors and misconceptions, and how they organize classroom interaction. Shulman (1986) conceptualized pedagogical content knowledge (PCK) as an important dimension of teachers' professional knowledge, emphasizing that effective teaching requires more than subject-matter knowledge. Ball et al. (2008) subsequently highlighted the specialized mathematical knowledge required for teaching, including interpreting learners' mathematical thinking, selecting representations, explaining mathematical ideas, and making appropriate instructional decisions. Evidence from Nigeria reinforces this perspective. Oluwatayo and Fakinlede (2019) found that senior secondary students in Ondo State rated their mathematics teachers relatively highly in pedagogical content knowledge but relatively lower in assessment competency. Fekuno and Diri (2024) reported that professional development significantly influenced mathematics teachers' subject-content and pedagogical-content knowledge in Yenagoa Local Government Area of Bayelsa State. Similarly, Sodangi et al. (2022) reported low participation in professional development among science and mathematics teachers in Zamfara State and identified content knowledge and teaching pedagogy among areas requiring further development. Collectively, these findings indicate that mathematics pedagogy is influenced not only by instructional methods but also by teachers' professional knowledge, assessment competence, and continuing professional development. Pedagogical challenges in Nigerian mathematics education are therefore multidimensional. They involve teacher knowledge and professional competence, learners' prior knowledge and experiences, curriculum and assessment demands, instructional resources, classroom conditions, school-level support, and broader educational structures. Accordingly, this conceptual paper examines major pedagogical challenges confronting mathematics education in Nigerian secondary schools, considers their implications for mathematics learning, and proposes a framework for pedagogical improvement and educational reform.

Conceptualizing Pedagogy in Mathematics Education

Pedagogy encompasses the knowledge, decisions, strategies, interactions, and practices through which teaching and learning are organized. In mathematics education, it includes how teachers activate learners' prior knowledge, represent mathematical ideas, pose questions, facilitate discourse, respond to errors and misconceptions, assess understanding, and provide appropriate support for learners with different levels of mathematical knowledge (Ball et al., 2008; Shulman,

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1986). Effective mathematics pedagogy therefore requires the integration of mathematical content knowledge with knowledge of how particular mathematical ideas can be made accessible and meaningful to learners. Effective mathematics teaching should move beyond the transmission of rules and procedures. Learners require opportunities to develop conceptual understanding, procedural fluency, mathematical reasoning, communication, representation, and problem-solving. NCTM (2014) emphasizes teaching practices involving purposeful questioning, meaningful mathematical discourse, appropriate representations, reasoning and problem-solving tasks, productive struggle, and the use of evidence of learners' thinking. These practices position teaching as an interactive process in which teachers continuously interpret and respond to learners' mathematical thinking. In Nigeria, curriculum development provides an important policy context for mathematics pedagogy. The Nigerian Educational Research and Development Council (NERDC) is responsible for curriculum development and has published a revised Senior Secondary Education Curriculum for SS1–SS3, within which General Mathematics is a core and compulsory subject (Nigerian Educational Research and Development Council [NERDC], 2025a, 2025b). A formally developed curriculum, however, does not automatically guarantee effective classroom implementation. Its effectiveness depends partly on how teachers interpret curriculum expectations and translate them into meaningful learning experiences through appropriate tasks, representations, instructional strategies, assessment, and opportunities for mathematical reasoning. Pedagogical quality can therefore be understood in terms of the extent to which classroom practices enable learners to make sense of mathematical ideas, connect concepts and representations, communicate reasoning, apply knowledge, and develop both conceptual understanding and procedural fluency.

Theoretical Perspectives

This paper draws on three complementary perspectives: Constructivist Learning Theory, Social Cognitive Theory, and Pedagogical Content Knowledge (PCK)/Mathematical Knowledge for Teaching (MKT). Together, they explain how learner activity, learner beliefs, classroom environments, and teacher professional knowledge interact in mathematics teaching and learning.

Constructivist Learning Theory

Constructivist perspectives view learning as an active process through which learners construct and reorganize knowledge by connecting prior understanding with new experiences. In mathematics education, this perspective emphasizes meaningful engagement through reasoning, exploration, representation, discussion, problem-solving, and connections among concepts. Such an orientation is consistent with teaching practices that promote mathematical reasoning, discourse, purposeful questioning, and productive struggle (NCTM, 2014). Constructivism is particularly relevant to Nigerian mathematics classrooms because transmission-oriented practices may restrict opportunities for learners to develop mathematical meaning and communicate their reasoning. However, constructivism does not imply that teachers should withdraw from instruction. Teachers remain central through the selection and sequencing of tasks, questioning, scaffolding, feedback, and connections between learners' informal strategies and formal mathematical knowledge.

Social Cognitive Theory

Bandura's (1986) Social Cognitive Theory emphasizes reciprocal interactions among personal factors, behaviour, and environmental conditions. In mathematics learning, learners' beliefs about their mathematical capabilities can influence their effort, persistence, participation, and responses to

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difficulty, while classroom experiences can simultaneously shape those beliefs. Repeated failure, discouraging feedback, or limited opportunities to participate may weaken learners' mathematical self-efficacy. Conversely, successful learning experiences, constructive feedback, appropriate challenges, and supportive peer interaction may strengthen learners' beliefs in their capabilities (Bandura, 1986). This perspective therefore emphasizes that pedagogical reform should address both what learners understand and the classroom experiences through which they develop confidence and persistence as mathematics learners.

Pedagogical Content Knowledge and Mathematical Knowledge for Teaching

Shulman (1986) argued that effective teaching requires an integration of content knowledge and pedagogical knowledge. PCK concerns teachers' knowledge of how particular subject matter can be represented, explained, organized, and made comprehensible to particular learners. In mathematics, knowing how to perform a procedure does not necessarily mean knowing how to explain its underlying reasoning, anticipate misconceptions, select suitable representations, or interpret incorrect solutions. Ball et al. (2008) extended this perspective through the concept of Mathematical Knowledge for Teaching, emphasizing specialized mathematical knowledge needed for teaching. Research has also established PCK as an important construct in mathematics education and teacher education research (Depaepe et al., 2013). Thus, strengthening mathematics pedagogy requires professional development that integrates mathematical content, learner thinking, pedagogy, curriculum, assessment, and classroom practice.

Theoretical Integration

The three perspectives provide complementary explanations. Constructivism emphasizes active construction of mathematical knowledge; Social Cognitive Theory highlights the interaction among learner beliefs, behaviour, and environment; and PCK/MKT emphasizes teachers' specialized professional knowledge. Together, they suggest that effective mathematics pedagogy requires knowledgeable teachers, purposeful instructional design, active learner engagement, supportive classroom environments, and responsive assessment.

Major Pedagogical Challenges in Nigerian Secondary Schools

Teacher-Centred, Rote, and Procedural Instruction

An important concern in mathematics education is the predominance of practices in which teachers do most of the explaining and demonstrating while learners have limited opportunities to articulate, investigate, and justify mathematical ideas. Explicit instruction is not inherently ineffective; it can be valuable when combined with guided practice, reasoning, discussion, and problem-solving (NCTM, 2014). The difficulty arises when transmission-oriented instruction becomes dominant and learners primarily reproduce worked examples and routine procedures. Nigerian evidence provides support for examining more participatory approaches. Akinpelu et al. (2024) found that Senior Secondary II students exposed to mastery learning performed significantly better in geometric constructions than those taught through conventional instruction. Olumuyiwa and Akinsola (2021) similarly investigated interactive e-note and problem-solving strategies among junior secondary students in Kaduna State. These findings suggest that mathematics instruction can be strengthened when teacher explanation is complemented by guided practice, interaction, investigation, and problem-solving. Closely related to teacher-centred instruction is excessive reliance on rote learning. Procedural fluency is important, but learners also need to understand mathematical relationships,

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recognize when procedures are appropriate, and apply knowledge flexibly to unfamiliar situations (NCTM, 2014). Effective instruction should therefore establish connections between conceptual understanding and procedural fluency rather than treating mathematics as a collection of memorized rules.

Inadequate Mathematical Discourse and Differentiation

Mathematical discourse enables learners to explain, question, justify, compare, and evaluate mathematical ideas while allowing teachers to examine learners' thinking and misconceptions. NCTM (2014) identifies meaningful discourse as an important component of effective mathematics teaching. In classrooms dominated by closed questions and predetermined answers, learners may have limited opportunities to articulate reasoning. Similarly, treating errors merely as failures can discourage participation. Differentiation is another related concern. Secondary mathematics classrooms contain learners with different levels of prior knowledge, mathematical experience, confidence, and conceptual understanding. Because mathematics learning is cumulative, gaps in prerequisite knowledge can interfere with subsequent learning. Teachers therefore need to use questioning, formative assessment, flexible grouping, scaffolded tasks, multiple representations, and targeted feedback to respond to differences among learners. Differentiation does not require completely separate lessons for individual students; rather, it involves purposeful adjustments that enable learners with different needs to participate meaningfully in mathematical activity.

Examination-Oriented Teaching and Assessment

Examination demands are an important contextual influence on mathematics teaching. Where examination performance receives disproportionate emphasis, teachers may experience pressure to cover content rapidly and prepare learners for familiar question formats. This may reinforce routine procedural practice at the expense of conceptual exploration and extended reasoning. Assessment should nevertheless provide information that can guide teaching and learning. Formative assessment enables teachers to identify learners' understanding, misconceptions, and developing reasoning and to adjust instruction accordingly (Black & Wiliam, 1998; NCTM, 2014). Nigerian evidence also indicates a need to strengthen assessment competence. Oluwatayo and Fakinlede (2019), for example, reported differences between students' perceptions of teachers' pedagogical content knowledge and assessment competency. Examination materials also illustrate the range of mathematical tasks candidates are expected to handle, including interpretation, application of mathematical principles, geometry, and other problem-solving contexts (West African Examinations Council [WAEC], 2023). This reinforces the need for teaching that develops conceptual understanding, interpretation, reasoning, and problem-solving rather than focusing narrowly on procedural reproduction.

Limitations in Teacher Professional Development

Sustained professional development is essential for strengthening teachers' mathematical knowledge, PCK, assessment competence, and capacity to implement effective instructional practices. Teachers need opportunities to examine mathematical content, learners' thinking, instructional strategies, assessment evidence, technology, and classroom practice (Ball et al., 2008; Shulman, 1986). However, professional development may be constrained by financial, institutional, and logistical factors. Sodangi et al. (2022) reported challenges affecting professional-development participation among science and mathematics teachers in Zamfara State, while Fekuno and Diri

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(2024) found that professional development significantly influenced mathematics teachers' subject-content and pedagogical-content knowledge in Bayelsa State. These findings suggest that professional learning should extend beyond occasional workshops towards sustained and classroom-focused opportunities such as collaborative planning, peer learning, lesson study, and coaching.

Large Classes, Resources, Technology, and Contextualized Learning

Classroom conditions also shape the feasibility of effective mathematics pedagogy. Large classes can make it difficult to monitor individual reasoning, provide timely feedback, organize mathematical discussion, and differentiate instruction. Limited access to instructional resources may create additional constraints, particularly where teachers lack manipulatives, geometric models, visual representations, graphing tools, or appropriate digital resources. The issue is not simply whether technology is available but whether resources are used purposefully to support mathematical thinking. Uya (2023), for example, reported advantages associated with collaborative strategies and geoboard resources in mathematics learning in Akwa Ibom State. Similarly, contextualized problem-solving can help learners connect mathematics to finance, measurement, agriculture, business, engineering, statistics, technology, and everyday decision-making. Nigerian studies involving interactive, problem-solving, and collaborative approaches further suggest the value of giving learners opportunities to engage actively with mathematical ideas (Olumuyiwa & Akinsola, 2021; Uya, 2023).

Interrelationship among Pedagogical Challenges and Learning Outcomes

The identified challenges are interconnected rather than independent. Large classes and limited resources may make whole-class exposition more manageable than differentiated or collaborative activities. Examination pressure may reinforce procedural teaching because routine practice can appear to provide an efficient means of preparing learners for assessed content. At the same time, inadequate professional development may restrict teachers' capacity to implement and adapt alternative approaches. These conditions can interact with learners' prior knowledge. Learners with weak prerequisite knowledge may struggle with new concepts, while inadequate formative assessment may prevent teachers from identifying misconceptions early. Teachers may consequently respond with additional procedural explanations and worked examples, potentially increasing learners' dependence on teacher demonstrations. The result can be a cycle in which weak prior knowledge, limited diagnosis, procedural instruction, and restricted mathematical reasoning reinforce one another. The central conceptual position of this paper is therefore that mathematics learning outcomes should not be examined independently of the pedagogical environment. Achievement, conceptual understanding, reasoning, and problem-solving are shaped by interactions among teacher professional knowledge, instructional practices, assessment, classroom conditions, resources, and learners' prior knowledge and experiences.

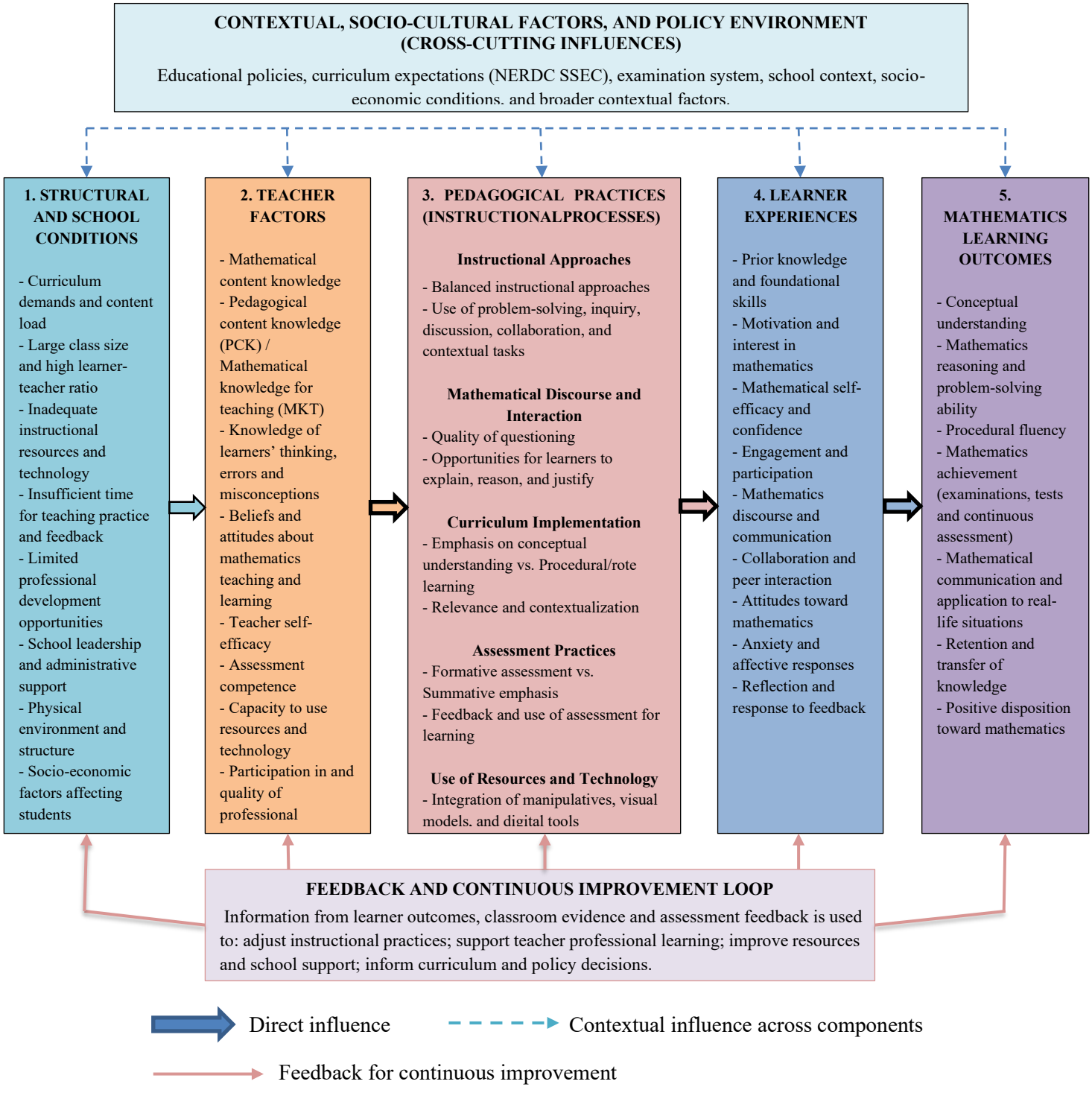
Proposed Conceptual Framework

Based on the foregoing theoretical and conceptual perspectives, Figure 1 presents the proposed framework for understanding the relationships among structural conditions, teacher factors, pedagogical practices, learner experiences, and mathematics learning outcomes in Nigerian secondary schools.

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Figure 1:
Conceptual Framework for Pedagogical Challenges and Mathematics Learning Outcomes in Nigerian Secondary Schools



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Note: The arrows represent proposed conceptual relationships among the components and should not be interpreted as evidence of direct causal effects. The solid arrows indicate the proposed primary pathway through which structural and school conditions and teacher factors may shape pedagogical practices, learner experiences, and mathematics learning outcomes. The framework is conceptual and interactive rather than strictly linear or causal, and the relationships represented are propositions requiring empirical examination.

The framework conceptualizes mathematics learning outcomes as emerging from interactions among structural and school conditions, teacher factors, pedagogical practices, and learner experiences. Structural conditions such as class size, resources, curriculum demands, examination pressures, and school support shape the context of teaching. Teacher factors, including mathematical knowledge, PCK, professional competence, beliefs, self-efficacy, and professional development, influence teachers' pedagogical decisions. These conditions are expressed through instructional practices, mathematical discourse, assessment, differentiation, and purposeful use of resources and technology. Such practices shape learners' engagement, prior-knowledge activation, self-efficacy, participation, and mathematical understanding. Learners' responses, misconceptions, engagement, and assessment evidence can, in turn, inform subsequent instructional decisions and professional learning.

Educational Implications and Reform Strategies

The conceptual analysis suggests that improving mathematics education requires reforms that address pedagogical practices together with the conditions that shape them. Five interrelated strategies are particularly important.

1. Strengthen Teachers' Professional Knowledge and Continuous Development: Teacher education and professional development should integrate mathematical content knowledge, PCK/MKT, learner thinking, assessment, instructional design, and reflective practice. Professional learning should be sustained and classroom-focused rather than limited to isolated workshops.
2. Promote Conceptually Focused and Learner-Centered Pedagogy: Teachers should balance explicit explanation with guided inquiry, collaborative problem-solving, mathematical discourse, representations, and opportunities for independent reasoning. The aim should be to develop conceptual understanding and procedural fluency together rather than treating them as competing goals.
3. Strengthen Formative Assessment and Foundational Knowledge: Teachers should use diagnostic tasks, questioning, classroom discussion, written responses, and feedback to identify misconceptions and gaps in prerequisite knowledge. Such evidence should inform subsequent instruction and targeted support.
4. Improve Instructional Resources, Technology, and Contextual Responsiveness: Education authorities and schools should improve access to affordable and contextually appropriate mathematics resources. Where digital technologies are available, teachers should be supported to use them for visualization, exploration, feedback, communication, and problem-solving rather than merely for presentation.
5. Strengthen Supportive Classroom Cultures and Curriculum–Assessment Alignment: Mathematics classrooms should encourage learners to explain and justify their reasoning, consider alternative strategies, and learn from errors without humiliation. At the system level, curriculum and assessment policies should place greater emphasis on conceptual understanding, mathematical reasoning, interpretation, and problem-solving.

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Research Gaps and Future Directions

The Nigerian literature provides useful evidence on individual instructional strategies and teacher competencies, but more systematic research is needed on how multiple pedagogical factors interact. Future studies should therefore move beyond isolated comparisons of teaching methods and investigate relationships among teacher knowledge, classroom practice, assessment, learner characteristics, and contextual conditions. Longitudinal and classroom-observation studies could examine how professional development translates into changes in teaching practice and learner outcomes. Research should also compare rural and urban schools, school types, class sizes, resource conditions, and geopolitical contexts. Further investigation is needed into how teachers' Mathematical Knowledge for Teaching interacts with learners' prior knowledge, self-efficacy, and problem-solving ability. Such evidence would provide a stronger basis for context-sensitive pedagogical reform in Nigeria.

Conclusion

Pedagogical challenges are an important dimension of the difficulties confronting mathematics education in Nigerian secondary schools. These challenges cannot be adequately explained by learners' motivation or by teachers' choice of instructional method alone. Rather, mathematics learning is shaped by an interconnected system involving teacher professional knowledge, pedagogical practices, assessment, curriculum demands, classroom conditions, professional development, resources, and learners' prior knowledge. The central argument of this paper is that sustainable improvement requires a shift from predominantly transmission-oriented practices towards pedagogy that combines clear explanation with conceptual understanding, mathematical discourse, problem-solving, formative assessment, differentiation, and active learner participation. Nigerian evidence indicates that approaches such as mastery learning, interactive instruction, collaborative learning, problem-solving, and purposeful use of instructional resources can provide useful directions for improvement. Ultimately, meaningful reform requires more than introducing new teaching methods. It requires strengthening teachers' professional knowledge, improving assessment practices, addressing foundational learning needs, providing supportive classroom conditions, and aligning curriculum and assessment with the mathematical competencies' learners are expected to develop. The proposed framework provides a conceptual basis for examining these relationships and for guiding future empirical research into mathematics pedagogy in Nigerian secondary schools.

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Influence of Students' Perception on Enrolment Decision in Mathematics Education Programmes among Tertiary Institutions of Learning in Cross River State, Nigeria

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Abstract

This study investigated The Influence of Students' Perception on their Enrolment Decision in Mathematics Education Programme in Tertiary Institutions in Cross River State. Three research questions and three hypotheses each were formulated to guide the study. A regressional research design was adopted for the study. A census sampling technique was applied for the total population of 140 undergraduate students in Mathematics Education Programme across the four tertiary institutions selected in Cross River State. A Perception of Students' Enrolment (PISE) questionnaire with 23 items was used to collect data. This instrument was subjected to face and content validity. The reliability coefficient of .923 was obtained using Cronbach Alpha Statistics. The research questions were answered using mean and standard deviation while one sample t-test, independent sample t-test and simple linear regression was used to test the hypotheses at 0.05 level of significance. The result revealed that students in tertiary institutions hold significantly positive perception of Mathematics Education with no gender disparity in perception. More so, the result showed that perception significantly influence students Enrolment decision in Mathematics Education Programme in Tertiary Institutions in Cross River State, Nigeria.

Keyword: students' perception, enrolment decision, mathematics education, tertiary institutions

Introduction

Mathematics has been defined by many scholars as a science of numbers, measurement of quantities, and pattern. It is the science of life as it cuts across all aspect of life, little wonder some say Mathematics is life and living. It plays a fundamental role in national development serving as the foundation for scientific and technological advancement. (Ekwueme, 2024) defined it as the study of numbers, quantities, shapes and patterns and that it also involves the use of symbol, rules, and logical reasoning to quantify relationships and solve problems. It pervades all aspects of life. The discipline not only equips individuals with essential problems solving and analytical reasoning skills (Wilson, 2020) but also underpins progress in a range of fields from engineering and natural sciences to finance and social sciences. In many parts of the world, Mathematics Education is seen as the bedrock upon which modern innovations are built. Mathematics serves not only as a tool for measurement and calculation but also as a means for conceptualizing and solving complex problems. This universality enables individuals to apply Mathematical concepts to real-world situations, thus enhancing critical thinking and analytical skills. For instance, Mathematicians and Statisticians are

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increasingly consulted in fields such as public health to model disease spread or in economics to predict market trends. In Nigeria, where economic development is a priority, fostering robust Mathematical Education can prepare a workforce capable of addressing the nation's unique challenges through data analysis, forecasting, and decision-making (Eze, 2023). The quality of Mathematics Education directly impacts overall educational outcomes. Students are more likely to pursue Mathematics related courses and can perform better with quality Mathematical instruction. Furthermore, effective Mathematics Education equips students with essential life skills such as logical reasoning, problem-solving, and the ability to analyze and interpret data which are skills highly valued in the 21st century (Alabi, et al., 2022).

The Nigerian government has recognized the need to reform Mathematics Education programme as part of larger educational improvements (NPE, 2020), thus various initiatives aim to enhance the quality of teaching and learning through teacher training, curriculum development, and resource allocation. However, reform efforts must be coupled with strategies that address students' perceptions and interest toward Mathematics Education as a career. Engaging students through technology, project-based learning, and real-life applications can make Mathematics more relevant and relatable, thereby fostering a more positive perception of the subject (Asuquo, 2021). The quality of instruction in Mathematics significantly influences students' perception and interests in the subject. Research shows that teacher effectiveness, pedagogy, and classroom environment can either promote or diminish a student's perception and interest in Mathematics (Ogundokun & Adeyemi, 2022). The importance of Mathematics Education in Nigeria is multifaceted, touching on individual student outcomes, national educational goals, and broader socioeconomic development. In Nigeria, the importance of Mathematics is given prominence by its integration into the national curriculum as a compulsory subject, intended to nurture logical reasoning and quantitative skills among learners from early education through tertiary levels (Kasim, et al., 2022). Mathematics Education programme in tertiary institutions is a programme intended to help train Mathematics educators who will help to change the wrong perceptions of Mathematics as a difficult subject and increase students' interest. It is crucial as it equips prospective Mathematics educators in problem-solving skills, enhance their career opportunities, improve their cognitive abilities, contribute to societal progress, and support interdisciplinary studies.

In Cross River State Nigeria, the hub of educational and cultural activities, the issue of fluctuation in students' enrolment in Mathematics Education is becoming increasingly pronounced. Cross River State, Nigeria hosts several tertiary institutions that have traditionally been seen as centers for academic excellence. However, recent enrolment data and anecdotal evidence suggest a significant fluctuation and dwindle in the number of students choosing Mathematics Education as their field of study. This trend is alarming for several reasons. Firstly, it threatens to create a vacuum of qualified Mathematics educators, which will have a ripple effect on basic and secondary education where Mathematics competency is crucial for fostering future innovators and professionals (Okonkwo et al., 2021). Secondly, a sustained decline in students' enrolment in Mathematics Education could undermine broader national goals of scientific advancement and economic competitiveness, as fewer students are likely to contribute to the technological and analytical workforce needed in the 21st century. This fluctuation and dwindling enrolment may be a predictive influence of students' perception and interest. Perception is the way individuals interpret information, experiences, and stimuli regarding a particular subject (Ogunleye, 2021). In the context of Mathematics Education, perception encompasses students' attitudes, beliefs, and emotional responses to Mathematics as a

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discipline. In Nigeria, the perception of Mathematics as an inherently challenging subject is well-documented in various studies. Ekwueme (2024) noted that most of the challenges students have in comprehending Mathematics is due to wrong perception. This prevailing view poses significant implications for student Enrolment and success in Mathematics-related fields especially Mathematics education program. The fear of Mathematics, often termed "Mathematics anxiety," is a psychological condition that manifests as apprehension or fear when faced with mathematical tasks. It is a significant barrier that can deter students from pursuing further studies in Mathematics-related fields (Kisanga, 2022). Research has shown that Mathematics anxiety undermines students' confidence, leading to avoidance behaviors that ultimately impact their academic performance (Cokley et al., 2023). The roots of negative perceptions regarding Mathematics education can often be traced back to secondary education. A study by (Osonwa, 2021) highlights the realities of many Nigerian secondary schools, where insufficient training and support for Mathematics teachers often lead to ineffective pedagogy. Many teachers rely heavily on traditional instructional methods, which can leave students disengaged and anxious about their mathematical abilities (Okoro, 2022). Research indicates that students frequently encounter Mathematics taught in a fragmented or overly theoretical manner, which fails to connect mathematical concepts to real-world applications (Ogunlaja, 2023). The perception of Mathematics in Nigeria is deeply influenced by various factors, including individual experiences, societal attitudes, and the quality of education.

Gender plays a crucial role in shaping students' perceptions and interest towards Mathematics education. In Nigeria, and specifically in Cross River State, cultural, social, and educational factors continue to influence how male and female students perceive Mathematics. These perceptions, in turn, affect their enrolment choices in Mathematics education programme in tertiary institutions. An understanding of these dynamics is essential for promoting gender equity in education and encouraging greater participation of both genders in Mathematics education programme. Cultural perception towards gender contributes significantly to the disparities observed in perceptions of Mathematics among students. Traditionally, Mathematics has been viewed as a male-dominated field, leading to the reinforcement of stereotypes that portray males as more adept in Mathematics than females (Ijeoma et al., 2023). In Cross River State, as in many parts of Nigeria, societal norms often dictate that boys are encouraged to excel in STEM (science, technology, engineering, and Mathematics) subjects, whereas girls may face pressure to conform to roles that prioritize social sciences or humanities over Mathematics. This gender bias in educational settings can lead to diminished self-confidence among female students. Research indicates that girls who internalize these societal beliefs may develop Mathematics anxiety, resulting in negative perception, lower academic performance and decreased interest in pursuing Mathematics education (Kisanga, 2022). Consequently, this anxiety can contribute to a cycle of under-Enrolment of females in Mathematics education programme at the tertiary level.

Statement of the Problem

Despite Mathematics being a critical foundation for technological advancement, economic growth, and problem-solving across disciplines, there is an alarming and persistent fluctuation in students' Enrolment in Mathematics education programme in tertiary institutions across Nigeria and notably in Cross River State. This trend is not just a concern for the academic community; it is a national challenge with far-reaching implications for the country's future development. The shortage of trained Mathematics educators threatens the quality of teaching at all levels of education and compromises the ability of future generations to compete in an increasingly data-driven and

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innovation-centered global economy.Tertiary institutions in Cross River State, once regarded as vibrant centers of academic excellence, are now witnessing sharp fluctuation in students opting for Mathematics education. Table 1 is a seven (7) years data of the number of students enroled into Mathematics education programme in University of Calabar (UNICAL), University of Cross River State (UNICROSS), University of Education and Entrepreneurship, Akamkpa and Federal college of Education Obudu in Cross River State Nigeria.

TABLE 1: Students enrolment across tertiary institutions in cross river state

Year	UNICAL B.Sc,Ed	UNICROSS B.Sc,Ed	UEE, Akamkpa B.Sc,Ed	FCE, Obudu B.Sc,Ed
2024/2025	10	5	19	6
2023/2024	2	6	4	6
2022/2023	19	7	5	8
2021/2022	23	8	4	10
2020/2021	18	8	10	4
2019/2020	8	9	16	20
2018/2019	13	12	20	18
	93	55	78	72

Source: Four Institutions Departmental Enrolment data

From the statistics in the Table 1, it can be seen that for seven years, only 93 students enrolled for Mathematics education programme in UNICAL, 55 enrolled in UNICROSS, 78enroled in University of Education and Entrepreneurship, Akamkpa and 72 students in Federal College of education Obudu. Out of this data, about 60% either dropped out or switched to other programmes, remaining like 40%. Furthermore, records from the University of Calabar Department of Mathematics Education shows that Enrolment dropped from 87 students in 2008 to 34 students in 2023, representing a 61% decrease. Similar trends are evident in other institutions across the state (University of Calabar, 2023). It is therefore pertinently clear that there is negative perception, low interest leading to this fluctuation in students' Enrolment in Mathematics education programme. The question arises: why are students losing interest and turning away from a subject so integral to national progress? Is it the perceived difficulty of the subject, lack of job opportunities, poor learning environments, or societal misconceptions about the value of Mathematics as a career path? Without clear answers and targeted interventions, this downward trajectory will persist, resulting in a widening gap in STEM fields, a decline in educational standards, and a workforce ill-equipped for the challenges of the modern world.

Null Hypotheses

1. Student's perception does not significantly influence their Enrolment decision in Mathematics education programme.
2. Students in tertiary institutions do not have a significantly positive perception of Mathematics education programme.
3. There is no significant difference in the mean perception of male and female students towards Mathematics education programme

Research Methodology

The study adopted a survey design with linear regression approach. This approach is deemed most suitable as the research aims to determine the influence of students' perception on their Enrolment decision in Mathematics education programme in tertiary institutions in Cross River State. The area of the study is Cross River State, located in the South-South geopolitical zone of Nigeria and bordered by the Atlantic Ocean to the South. It is geographically situated between latitudes 4.0° N and 6.0° N

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and Longitude 8.0° E and 10.0° E. The target population includes 140 undergraduate students initially enrolled into Mathematics education programme across selected tertiary institutions in Cross River State as shown in table 2. These are students from universities and colleges of education, offering Mathematics education programme. Specific groups were segmented based on year of study (e.g., first-year, second-year) to assess how perception change throughout the academic journey. There was no sample as all the population comprising of all 140 undergraduate students (from year one to final year) studying Mathematics education, drawn from the four selected institutions in Cross River State offering Mathematics education programme was used.

TABLE 2: Sample distribution of the institutions

S/N	Institution	Number of students
1	University of Calabar	52
2.	University of Cross River State	26
3.	University of Education and Entrepreneurship Akamkpa	32
4.	Federal College of Education Obudu	30
	TOTAL	140

Source: Institutions departmental Enrolment data

The primary instrument for data collection was a survey, specifically a structured questionnaire. The researcher developed a Perception of Students' Enrolment (PSE) questionnaire, comprising four (3) distinct sections with twenty-three (23) number of items used to test the hypotheses and answer the research questions. Section A collected crucial demographic data: gender, institution, and level (year 1 to year 4). Section B employed ten (10) items on a 4-point scale, ranging from Strongly Agree to Strongly Disagree, to gauge student's perceptions towards Mathematics education program. Section C was ten (10) items set to measure the influence of perception on students' Enrolment decision in Mathematics Education Programme. The reliability of the PSE instrument was established through a pilot study involving 30 students outside the sampled population to determine the consistency of the instrument. The responses were analyzed on Cronbach Alpha yielding a reliability coefficient of .923, based on the variables respectively as shown in table 3. Cronbach's Alpha was applied because the instrument was polytomously scored (i.e, responses had multiple categories of strongly agree, disagree and strongly disagree)

Discussion of Findings

Hypothesis 1: Student's perception does not significantly influence their enrolment decision in Mathematics education programme. This hypothesis was analysed using simple linear regression.

TABLE 3: Summary of the analysis of simple linear regression on the influence of perception on students Enrolment decision in Mathematics education programme (N=140)

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	40.922	5.429		7.537	.000	30.187	51.658
PERCEPTION	.675	.175	.311	3.850	.000	.328	1.021

a. R = .311[a], R Squared = 0.97 (Adjusted R Squared = .090) *Significant at p>0.05

ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1671.173	1	1671.173	14.820	.000[b]
	Residual	15561.649	138	112.766		
	Total	17232.821	139			

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Source: Researcher's field work 2025

The findings of hypothesis 1, as presented in Table 3, provide empirical evidence on the influence of students' perception of Mathematics education programmes on their Enrolment decisions. The simple linear regression analysis revealed that students perception significantly influence their enrolment decision in Mathematics education ($\beta = .311$, $t = 3.850$, $p = .001$). This shows that an improvement in students' perception of Mathematics education programmes can increase likelihood of Enrolment. This result underscores the explanatory value of perception beyond mere association, showing that it contributes independently to students' Enrolment decisions. Moreover, the coefficient of determination indicates that students' perception accounts for approximately 9.7% of the variance in Enrolment decision ($R^2 = .097$; adjusted $R^2 = .090$). While this proportion of explained variance is relatively large, it is nonetheless meaningful in the context of educational decision-making, where Enrolment choices are typically influenced by multiple interrelated factors such as career prospects, societal attitudes, personal interest, and academic self-efficacy. The finding therefore implies that perception is a significant contributor to Enrolment decisions in Mathematics education programmes. The ANOVA result further confirms the robustness of the regression model. The model was found to be statistically significant ($F(1,138) = 14.820$, $p = .001$), indicating that it provides a better fit to the data than a model with no predictor. This validates the suitability of students' perception as a predictor of Enrolment decision within the study context. In all, the findings of hypothesis one demonstrate that students' perception of Mathematics education programmes has a statistically significant and positive influence on their Enrolment decisions. Consequently, the null hypothesis is rejected. This result highlights the importance of fostering positive perceptions of Mathematics education among prospective students, as such perceptions can contribute to increased Enrolment in Mathematics education programmes, even though other factors may also play substantial roles.

This finding aligns with numerous previous studies demonstrating perception's influence on Enrolment. Usman and Memeh (2021) reported a strong positive correlation ($r = 0.68$, $p < .001$) with perception accounting for 31% of variance in program choice in North-Central Nigeria. Abe and Gbenedio (2014) found that perception was a significant predictor ($\beta = 0.48$, $p < .001$) with the combined model explaining 43% of variance. Okonkwo and Obinne (2020) demonstrated that perception significantly influence Enrolment ($\beta = 0.62$, $p < .001$), correctly predicting 76% of Enrolment decisions. The stronger prediction observed in the present study ($r = .311$, $R^2 = .097$) compared to these previous studies may reflect methodological differences. Many previous studies examined prospective students or first-year students making Enrolment decisions, whereas the present study examined students already enrolled and progressing through their programs. For currently enrolled students, perceptions may be consequences as well as causes of Enrolment decisions, with the experience of studying Mathematics education influencing perceptions retroactively. Additionally, studies that examined perception of Mathematics as a subject (Adebayo & Olorunsola, 2019; Nnamdi & Ugwu, 2023) often found stronger relationships than the present study, which focused specifically on perceptions of Mathematics education as a program of study.

The distinction between subject perception and programme perception may be important, as students could have positive perceptions of Mathematics while holding different views about Mathematics education as a career path. The finding that perception's predictive power is significant (explaining only 9.7% of variance) supports Ekwueme's (2024) observation that perception works in conjunction with other factors. Studies examining multiple predictors simultaneously (Nnamdi & Ugwu, 2023; Osita & Eze, 2022) found that when perception was combined with other variables like

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self-concept, teaching profession perception, and institutional perception, explained variance increased substantially to 45-52%. The practical implication is that while improving student perceptions of Mathematics education programme is important and does influence Enrolment decisions, perception alone is insufficient to explain Enrolment patterns. Other factors such as interest, career prospects, family influence, and teaching quality also play crucial roles, as documented by Abe and Gbenedio (2014) and Adeoye et al. (2021).

Hypothesis 2: Students in tertiary institutions do not have a significantly positive perception of Mathematics education programme. This hypothesis was analysed using simple linear regression. This is presented in Table 4.

TABLE 4: Summary of One-Sample t-test results for students' perception of mathematics education programme (N=140)

Variable	T	Df	Sig. (2-tailed)	Mean Difference	Cohen's d	95% confidence Interval of the Difference	
						Lower	Upper
Perception	70.341	139	.000	30.550	5.945	29.6913	31.4087

Source: Researcher's field work 2025

Results relating to hypothesis two, as presented in Table 4, revealed that the calculated t-value of 70.341 at 139 degrees of freedom, with a Cohen's d effect size of 5.945, yielded a probability value ($p = .001$) which is significantly lower than the 0.005 level of significance. This result indicates a statistically significant outcome; consequently, the null hypothesis was rejected. The implication of this finding is that students in tertiary institutions in Cross River State, generally hold a statistically positive perception of the Mathematics Education programme, as evidenced by an overall mean perception score of 30.55. Notwithstanding this overall positive disposition, a closer examination of the responses revealed the presence of divergent views among the students. Specifically, a considerable proportion of respondents expressed low or negative perceptions of the programme. These students perceived Mathematics Education as difficult, abstract, and intellectually demanding, with limited career prospects beyond classroom teaching. Such perceptions appear to undermine the attractiveness of the programme to prospective and continuing students. This coexistence of positive aggregate perception alongside notable negative sentiments provides a plausible explanation for the persistent decline and fluctuation in enrolment figures observed across the tertiary institutions examined. While the programme is positively regarded at a general level, the enduring negative stereotypes and career-related concerns held by a significant segment of students may be contributing to reduced enrolment interest and instability over time. This finding contrasts sharply with several previous studies that reported predominantly negative perceptions. For instance, Ogunleye and Adeyemi (2021) found that 68% of secondary school students in Lagos State associated Mathematics with difficulty and held moderately negative perceptions (mean = 2.31). Similarly, Kisanga (2022) reported that 54% of pre-service teachers in Tanzania held negative perceptions about Mathematics education, citing Mathematics anxiety and perceived difficulty as major contributors. However, the present findings align more closely with studies by Nwankwo et al. (2022) and Alabi et al. (2022), who found that when students have exposure to real-world applications and supportive educational environments, their perceptions of Mathematics improve substantially. The positive perceptions observed in Cross River State may reflect several contextual factors: the students in this study are already enrolled in Mathematics education programs and have made a commitment to the field, unlike the general student populations examined in many previous studies. This self-selection effect likely contributes to more positive perceptions. The particularly

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high scores on career preparation (M = 3.37) and employability enhancement (M = 3.12) suggest that students perceive practical value in their Mathematics education training. This finding supports Ogunlaja's (2023) observation that perceived relevance to future careers significantly influences Mathematics perceptions. The moderate disagreement with statements about Mathematics education not being an important profession (M = 3.24) and not seeing relevance in real life (M = 3.12) indicates that students recognize the societal value of Mathematics education, contradicting the low societal regard concerns reported by Eze (2023). The relatively lower scores on some items, such as wanting to switch programs (M = 2.81) and finding the subject difficult (M = 2.74), suggest areas where perceptions could be further strengthened. These findings resonate with Okoro's (2022) emphasis on the importance of teaching quality and Asuquo's (2021) demonstration that technology-enhanced instruction significantly improves Mathematics perceptions.

Hypothesis 3: There is no significant difference in the mean perception of male and female students towards Mathematics education programme. This hypothesis was analysed using simple linear regression. This is presented in Table 5.

TABLE 5: Independent Samples t-test Result for Gender Differences in Perception (N=140)

	F	Sig	T	Df	Sig. (2-tailed)	Cohen's d	Mean Difference	Std Error Difference	95% confidence interval of the difference	
									Lower	Upper
Equal variance assumed	6.167	0.14	.650	138	.517	.114	.58757	.90438	-1.201	2.376
Equal variances not assumed			.592	78.733	.556		.58757	.99244	-1.388	2.563

Source: Researcher's field work 2025

The result of hypothesis three, as presented in Table 5, revealed that the independent samples t-test produced a calculated value of t = .592 with 78.733 degrees of freedom and a corresponding p-value of .556 (2-tailed), which is greater than the stipulated alpha level of 0.05. In addition, the effect size estimate, Cohen's d = .114, indicates a small and practically negligible difference between the two groups. Based on this outcome, hypothesis three was accepted and retained. This finding demonstrates that there is no statistically significant difference in the perceptions of male and female students toward Mathematics education programmes in tertiary institutions. Although male students recorded a marginally higher mean perception score (M = 30.76) compared to their female counterparts (M = 30.18), this observed difference is not sufficient to attain statistical significance. Therefore, students' perceptions of Mathematics education programmes appear to be consistent across gender, suggesting that gender does not play a determining role in shaping perception within the context of this study. This finding contradicts numerous studies that have consistently reported significant gender differences favoring males in Mathematics perceptions. For instance, Ijeoma et al. (2023) found significant gender differences ($t = 3.89$, $p < .001$) with male students showing more positive perceptions (mean = 3.78) compared to females (mean = 3.21) across five Nigerian universities. Similarly, Ekwueme (2024) reported significant gender differences ($t = 5.67$, $p < .001$, $d = 0.76$) in Ebonyi State, with 68% of female students believing they were naturally less capable in Mathematics. Other studies by Olaniyi and Olatunji (2021), Adeyemi and Ogunleye (2022), Bamidele

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and Adeoye (2022), and Akpan and Etuk (2021) all documented significant gender gaps in Mathematics perceptions favoring males.

The absence of significant gender differences in Cross River State Mathematics education students represents an important and positive finding. Several factors may explain this departure from previous research. First, the population studied consists of students already enrolled in Mathematics education programs who have demonstrated commitment to the field regardless of gender. This self-selection may have filtered out students with the most negative gender-stereotyped perceptions. Second, Cross River State institutions may have created more gender-equitable learning environments that minimize stereotype threat and gender bias, as suggested by the low scores on perceived gender bias in teaching for both males (M = 2.45) and females (M = 2.53). Third, the finding that both genders reported high confidence in their mathematical abilities (Male M = 3.25, Female M = 3.41) and similar perceptions of institutional support (Male M = 3.35, Female M = 3.33) suggests that these programs have successfully countered traditional gender stereotypes. This aligns with research by Olaniyi and Olatunji (2021) and Adeyinka and Ndukwe (2022), which found that when teacher attitudes and institutional support are positive, gender differences in perception diminish or disappear. Interestingly, female students reported seeing more female role models (M = 3.35) than males reported (M = 3.12), though both scores were above neutral. This visibility of female role models may have contributed to the gender parity in perceptions, supporting the findings of Dwyer et al. (2024) that female role model presence significantly affects girls' Mathematics perceptions.

Conclusion

Tertiary institutions have been relatively successful in attracting students with favourable dispositions toward Mathematics education and maintaining positive programme experiences. However, the persistence of fluctuating enrolment despite these positive characteristics among enrolled students suggests that the challenge lies more in recruitment and initial enrolment attraction than in programme quality or student satisfaction once enrolled. The achievement of gender parity in perceptions represents a significant accomplishment for Cross River State Mathematics education programme. Unlike many Nigerian contexts where substantial gender gaps persist, Cross River State institutions appear to have created learning environments that equally support and engage both male and female students. This gender equity should be recognized, studied, and potentially replicated in other states facing persistent gender disparities in Mathematics education. The moderate strength of perception as influence indicates that Enrolment decisions are multifactorial. Other influences not measured in this study such as interest, family expectations, economic considerations, peer influence, institutional reputation, scholarship availability, alternative career opportunities, and quality of secondary school Mathematics experiences likely play important complementary roles. Understanding Enrolment patterns fully requires examining this broader constellation of factors.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Government and Educational Policymakers should develop and implement a comprehensive Mathematics Education Enhancement Initiative that prioritizes improving student perceptions and interest from primary through tertiary levels. This initiative should include adequate funding, clear implementation timelines, and measurable outcomes. They should also create a National Mathematics Education Awareness Campaign that showcases diverse career opportunities, highlights successful Mathematics educators, challenges stereotypes, and demonstrates the relevance of Mathematics to national development.

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2. Tertiary Institutions should establish Mathematics Education Resource Centers in each institution equipped with modern teaching aids, technology, and conducive learning spaces that create positive learning experiences and improve perceptions.
3. Students should actively engage with Mathematics content and teaching methods, seeking help when needed rather than allowing early struggles to develop into Mathematics anxiety or negative perceptions. Explore diverse career opportunities available to Mathematics education graduates, broadening understanding of the field's potential beyond traditional classroom teaching.

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Effect of Caregivers Instructional Strategies on Performance in Letter Identification among Early Special Need Learners in Ikom, Cross River State, Nigeria

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Abstract

This study investigated the effect of Caregivers' instructional strategies on letter identification performance of early special need learners in Ikom Education Zone of Cross River State, Nigeria. To guide the study, two specific objectives and corresponding research questions and hypotheses. The pre-test post-test quasi experimental non-equivalent group design was used for this study. The population of the study was 8,567 ECC I pupils in 383 public primary schools. Multi-stage sampling technique was used to select a sample size of 194 ECC I pupils from eight intact classes. Letter Identification Achievement Test (LIAT) was used as instrument for the study. Kuder Richardson Formula 20 was used to determine the internal consistency of letter Identification Achievement Test (LIAT) which yielded a coefficient index of .73. Mean analysis and standard deviation were used to answer the research question while analysis of covariance (ANCOVA) was used to test the hypothesis. The study revealed that there is a significant difference between the mean letter identification performance of pupils taught using tactile instructional strategy and those taught using pictorials. Based on the finding of the study, the researchers recommended among others that teachers should integrate tactile instructional strategy into teaching letter identification in the classroom.

Key Words: Instructional Strategy, Tactile Instructional Strategy, Early Special Need Learners.

Introduction

Man in his quest to transmit societal values that would transform the young child and make his society a better place to live, schemes for better ways of passing the desired knowledge and values that would make them functional. One of such ways is education. Education is the process of preparing the younger generation to be useful to themselves and society. Diernye in Morrison et al. (2023) see education as the preparation of individuals to fit into different roles and activities for the transformation of society. This therefore implies that education must involve conscious engagements which include planning, implementation, and evaluation. It also demands that the direction of progress and transformation must be defined if progress must be made.

Early Special Need learners are ECCE learners who need extra support or different teaching approaches because of physical, sensory, intellectual, communication or learning difficulties, they also include exceptionally gifted learners. Early learners with letters identification difficulties often have dyslexia (Bassey E.O and Ndifon F.O 2025). The National Policy on Education (NPE) (2014) sees the need for early preparation of the child for social, intellectual and moral adjustment and adaptation in society. To catch the child young, she prescribes Early Childhood Care Education (ECCE) as a preparation ground for the smooth transition of the child from the home to the primary

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education. According to Bassey E.O and Ndifon F.O (2025), Early Childhood Education ECE is the preparation by education and care given to children from home and educational institutions before the formal schooling in the basic school. Early Childhood Education (ECE) is a force for human dignity that caries lifelong benefit. Conscious of this, the FRN (2014), in section 13 of her NPE states in very clear terms the purpose of early childhood education which are; effect a smooth transition for primary level from the home to the school; prepare the child for primary level of education; promote adequate care and supervision for the children while their parents are at work (on the forms, in markets, offices, etc.); inculcate in child the spirit of inquiry and creativity through the exploration of nature, the environment, art, music and playing with toys etc; develop a sense of cooperation and team spirit, learn good habit, especially good health habit. And teach them rudiment of numbers, letters, colour shapes, form etc through play. The last of these objectives is to teach them rudiment of numbers, letters, colour shapes, form etc. through play. This implies that literacy development of the child cannot be injured at the pre-primary school level. In line with this recognition if letter is properly taught at the pre-school, the result will improve achievement in other levels of education and also effective teaching of letter identification at the pre-school will enhance and improve achievement in other levels of education.

Identification of the letters of the alphabet or alphabetic knowledge is essential for learning to read and write. Alphabet knowledge (AK) is consistently recognized as the strongest, most durable predictor of later achievement in literacy including decoding, comprehension, and spelling (National Early Literacy Panel 2008). English has an alphabetic writing system; letters in written words represent sounds in spoken words. The awareness that letters represent the sounds in spoken words is called the alphabetic principle. One of the basic steps in learning the alphabetic principle is recognizing and naming the letters of the alphabet. Children will also have to learn the sounds in words (phonemic awareness) and the letters that represent those sounds. Most strong readers acquire a working knowledge of the alphabetic principle by the middle of first grade. It is also helpful for children to learn to sequence the letters from A to Z because alphabetical order is the way we organize our letters. In early childhood education, caregivers' instructional strategies are the methods and techniques they use to support young children's development. These pedagogical approaches usually focus on active, play-based learning, like storytelling, games, group activities, and hands-on experiences rather than rote memorization. The idea is to create a child-centered environment that encourages curiosity, creativity, communication, and social interaction. Because children learn best when activities match their developmental needs and individual learning styles. So, effective strategies really shape how well children engage and perform in those foundational years, setting the stage for lifelong learning. Caregivers' pedagogical approaches with rooting on play range from tactile, conventional, pictorial, hand-over hand guidance to mention but a few. Letter identification performance has long been recognized as a potent predictor of later reading ability. Some studies suggest that although letter naming predicts the ability to read later on, it does not cause a child to learn more readily. Ehri (2025) however, suggested that letter name knowledge may be inseparable from letter-sound knowledge because so many letter names sound a great deal like the sound that is associated with them (for example, /m/ for the letter m). Gillon describes a "bi-directional" relationship between letter-name and phoneme awareness, where knowledge of one enhances knowledge of the other (Gibson and Levin 2023). Given the significance for children to successfully gain alphabetic knowledge, it is important to consider effective practices for teaching letter names, sounds, and written forms. Alphabetic knowledge initiates the first level of reading acquisition by facilitating the breaking down of words into letters. Later, in a critique of five studies

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of children's alphabet knowledge, Ehri (2025) went further and suggested that children's knowledge of the alphabet is the main skill that enables them to move from the first stage to the alphabetic or phonological stage of reading acquisition and that it is difficult to separate children's letter-sound knowledge from other emergent literacy skills. Chall (2003) summarized 17 studies of the relationship between knowledge of the alphabet and future reading achievement. Although causation was not claimed, knowledge of the letters of the alphabet was seen as an important predictor of reading achievement. To Sulzby (2023) children's letter identification ability is integrated into a more complex set of early literacy skills and that children attempt to use some mechanism as they learn to associate letter names with their visual forms.

Tactile instructional strategy refers to a method of teaching where learners are exposed to making or handling materials in the learning process. Tactile learners remember things better when they can use their fine motor skills to make or handle relevant materials while learning new or difficult work. They generally need to write or type notes while listening. They concentrate best when they can manually manipulate information in concrete formats, and they like to reinforce their understanding using other self-correcting resources. It is obvious therefore that the degree of interest and motivation a child derives from a learning environment may affect the child's performance. Salami and Egiethua (2022) observed that, tactile instructional strategy enhances the learning of new skills, knowledge and gaining of experience through active participation of learners in the process of knowledge acquisition. In tactile lessons, learners are engaged in activities that are learners initiated, that is, activities that are built upon the natural curiosity of the learners and real-life related issues are at the centre of learning letters. Conventional or pictorial teaching method is a method according to Gbamaja (2019) as cited in Shofoyeke (2015) called talk and chalk or textbook method. According to Slofoye, this is the most commonly used method by teachers in the teaching-learning process. This method is dominated by the teacher and the learner is subjected to little participation. Shofoyeke further reiterated that the direct teachers approach considers the teacher as the repository of all knowledge while the pupils are passive recipients of knowledge transmitted by the teachers in the teaching-learning process and this characterized it as teacher-centered. It limits the movement of children, giving them few opportunities to use activities to discover meaning. Quietness and orderliness are placed at a high premium than engagement of learners. Direct Instruction is seen as a highly structured approach that uses explicit teaching and well scripted lesson plan (Rumph et al., 2007 cited in Ewing, 2021). Any method that is teacher centered is an example of direct teacher's instruction such as lecture/expository method, demonstration method, etc. Conventional method of teaching is one of the most widely used teaching strategies but it has been criticized as ineffective and scorned at as a teaching method used by teachers who are not prepared.

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manipulatives and tangible representations of material encouraging pupils to take notes during lectures, providing opportunities to create artistic representations of learning (drawing, painting, etc.). A spelling technique that helps pupils who are tactile learners involves having pupils trace letters and words with their fingers. It is obvious therefore that the degree of interest and motivation a child derives from a learning environment may affect the child's performance. Conventional teaching method is a method according to Gbamaja (2019) called talk and chalk or textbook method. This is the most commonly used method by teachers in the teaching-learning process. This method is dominated by the teacher and the learner is subjected to little participation. It limits the movement of children, giving them few opportunities to use activities to discover meaning. Quietness and orderliness are placed at a high premium than engagement of learners. Direct Instruction is seen as a highly structured approach that uses explicit teaching and well scripted lesson plan (Rumph et al., 2007 cited in Ewing, 2021). Any method that is teacher centered is an example of direct teacher's instruction such as lecture/expository method, demonstration method, etc. Conventional method of teaching is one of the most widely used teaching strategies but it has been criticized as ineffective and scorned at as a teaching method used by teachers who are not prepared. Knoester (2022) posits that the traditional classroom is suppressive; it limits the movement of children, giving them few opportunities to use activity to discover meaning; quietness and orderliness are placed at a high premium than engagement of learners. Conventional method is seen as a highly structured approach that uses explicit teaching and well scripted lesson plan (Rumph, Ninnens, McCuller, Holland, Ward and Wilborn, 2007 cited in Ewing, 2021). Direct teachers' instruction is a teacher-centred pedagogy geared towards clear didactic communication. The teacher is considered as who possesses sound mathematical content knowledge as well as an expert who transfer this knowledge onto pupils through direct instruction, rote learning and rehearsal (Wing, 2021). Conventional classroom communication is characterized by "teacher dominated classroom talk, and most of the learners are silent for often time." Kalantzis, 2006 cited by Wing, 2021. Wing reiterated that this description is not quite appropriate for many letter identification classrooms where the teacher is the authority on letter knowledge, while the pupils are devoid of such knowledge. This research work is basically to investigate the effect of teaching children letter identification with tactile and conventional or pictorial strategies on their performance. Some empirical researches have been conducted on instructional strategies and learners' letters identification performance. Hosack (2016) conducted a study on the effects of conventional instructional strategies on fourth grade pupils' attitudes and performance in number work in Florida. The study adopted a quasi-experimental research design. The population of the study was 1045 and sample size of 126 elementary school on fourth grade pupils in a sub-urban area of Central Florida. The instruments used for data collection was qualitative data include pupils' journal entries, pupils' interviews, and teacher field notes, while the quantitative data was collected with pre-and post-anxiety survey and evaluative assessments. The data collected were analysed with percentage. The findings of the study indicated that the use of conventional instructional strategy decreased pupils' letter work anxiety, pupils, letter work attitude improved using hands-on instructional strategy, improve the performance of pupils. The study also revealed that pupils expressed a great deal of enthusiasm in making use of manipulative, games, cooperative groups and technology. On the contrary, White (2022) conducted a study on the effect of an instructional model, utilizing hands-on learning and manipulations on Mathematics achievement of middle school pupils in Georgia. The study adopted quasi-experimental design. The target population of the study was middle school Mathematics pupils in the United States, the sample size consisted of 100 pupils from two groups of seventh-grade Mathematics pupils in a middle school in North West Georgia. The instrument used was Mathematics Achievement Test. The instrument was administered

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on the pupils as pre-test, and the post-test. The data collection were analyzed with mean, standard deviation, Mann-Whitney U- test and analysis of covariance (ANCOVA). The findings of study revealed that there was no significant difference between the post-test scores of all of the participants in the control group and the entire participant in the experimental group. The result also showed that there were no significant differences between the post-test scores of the average- achieving mathematics pupils in the control group and the average achieving number work pupils in the experimental group, it also showed that there were no significant differences between the post-test scores of the high achieving mathematics pupils in the control group and the high achieving mathematics pupils in the experimental group. The study reviewed was carried out outside Nigeria and also in units in Mathematics. The present work was done in Nigeria and in units in Literacy. However, the design and method of data analysis in the above study were employed in this study. However, Margarita (2023) conducted a study on effect of kinesthetic/tactile stimuli on the learning words in the second language in Tilburg. The study adopted quasi-experimental research design. The population for the experiment consists of pupils from Tilburg University participant's pool in the Netherlands with a sample size of 38 pupils aged from eighteen to twenty-seven. The instruments used for data collection was Word-Pairs Test. The data collected were analysed with means, standard deviations and independent t-tests. The findings of the study indicated that the participants memorized more words in the condition one - not exposed to the additional kinesthetic stimuli, than while being in the condition two – being exposed to kinesthetic/tactile stimuli. This insignificant difference in number of words learned was balanced by the significantly increased level of engagement of pupils in the task of acquiring new words, while being exposed to kinesthetic/tactile stimuli. These findings relate to this study in that while more experiments in the field of kinesthetic learning are advised, in order to trace more precisely the positive or negative effect of the combination of brain and muscle functions on the way a human perceives new data, the positive effect of kinesthetic/tactile stimuli on the overall engagement of the pupils in the task of learning is clearly supported by this study.

Statement of the Problem

The high rate of difficulties in letter identification among early learners has continued to be a source of concern to all stakeholders in the education of children at this level. This is because of its implications for the quality of education at the higher levels. The poor letter identification of pupils among has been attributed to the use of poor instructional strategies by teachers. It is evident that the vast majority of pupils have difficulties in letter identification. This disturbing phenomenon is not without its many negative ramifications especially given the fact that letter identification correlates with reading and writing achievement. The slow and poor performances of preschoolers in letter identification have been attributed to the use of conventional instructional methods, and poor strategies by instructors. Therefore, it is based on this that, the researcher sought to determine the effect of teachers' instructional strategies on letter identification performance of preschool pupils in Ikom education zone of Cross River State, Nigeria.

Purpose of the Study

The study investigated the effect of teachers' instructional strategies on letter identification performance of preschool pupils in Ikom education zone of Cross River State, Nigeria Specifically, the study seeks to: Ascertain the difference between the mean letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials. Ascertain the difference between the mean letter Bb identification performance of pupils taught using tactile instructional strategy and those taught using pictorials.

Research Questions

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The following research questions were stated to guide the study:

1. What is the difference between the mean letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials?
2. What is the difference between the mean letter Bb identification performance of pupils taught using tactile instructional strategy and those taught using pictorials?

Research Hypotheses

The following null hypotheses were formulated to guide this study:

HO_1: There is no significant difference between the mean letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials.

HO_2: There is no significant difference between the mean letter Bb identification performance of pupils taught using tactile instructional strategy and those taught using pictorials.

Research Methodology

This study adopted quasi-experimental research design. Specifically, it is a pretest – post-test non-equivalent control group design. Quasi-experimental design is a design in which random assignment of subject to treatment and control groups is not possible (Ali, 2016). The study area is Ikom education Zone of Cross River State the comprises of six local government areas of Abi, Boki, Etung, Ikom, Obubra and Yakurr. The total population of the study consisted of all 8,567 ECC 1 pupils in 383 public primary schools in Ikom education Zone (SUBEB, 2025). A multi-stage sampling technique was adopted to select 194 ECC1 learners from eight intact classes used in the study. Letter Identification Achievement Test (LIAT) was the instrument used for the study. To ensure the validity of the instrument, the initial draft of a Letter Identification Achievement Test (LIAT) together with lesson plan on Letter Work were subjected to face and content validity by three experts. To establish the reliability of the instrument, the instrument was subjected to trial testing on 26 ECC 1 pupils in Ikom Education Zone who were not part of the population study but had same characteristics. Kuder Richardson Formula 20 was used to determine the internal consistency of Letter Identification Achievement Test (LIAT) which yielded reliability coefficient index of 0.73. This high reliability coefficient index indicated that the instrument was reliable and suitable for the study. Descriptive statistics such as mean analysis and standard deviation were used in answering the research questions while analysis of covariance (ANCOVA) was used to test the hypotheses at .05 level of significance. The pretest scores were used as covariates to partial out the initial differences between the experimental and control groups.

Presentation of Results

Research Question One

What is the difference between the mean letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials?

Table 1: Pretest-Posttest and mean difference in letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials

Group	Pre-test			Post-test		
	N	x	SD	X	SD	MeanDifference
Experimental group (Tactile instructional strategy)	99	0.69	1.27	2.45	1.16	1.76
Control group (pictorials)	95	0.56	1.18	1.04	1.43	0.48

Source: Field data (2025)

The result in Table 1 shows the mean difference in letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials. The result shows that

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the pretest mean of pupils taught with tactile instructional strategy (experimental group) was 0.69 with a standard deviation of 1.27 and a posttest mean of 2.45 with a standard deviation of 1.16. The difference between the pretest and posttest mean for pupils exposed to the experimental group was 1.76. On the other hand, the pretest mean of pupils exposed to pictorials (control group) was 0.56 with a standard deviation of 1.18 and a posttest mean of 1.04 with a standard deviation of 1.43. The difference between the pretest and posttest mean for pupils exposed to the control group was 0.48. From this result, it can be deduced that pupils exposed to tactile instructional strategy (experimental group) performed better than those exposed to pictorials (control group) in their identification of letter Aa.

Research Question Two

What is the difference between the mean letter Bb identification performance of pupils taught using tactile instructional strategy and those taught using pictorials?

Table 2: Pretest-Posttest and mean difference in letter Bb identification performance of pupils taught using tactile instructional strategy and those taught using pictorials

Group	Pre-test			Post-test		
	N	x	SD	x	SD	Mean difference
Experimental group	99	0.48	1.10	2.93	0.42	2.45
Control group (Pictorials)	95	0.44	1.06	1.35	1.50	0.91

Source: Field data (2025)

The result in Table 2 shows that the pretest mean of pupils taught with tactile instructional strategy (experimental group) was 0.48 with a standard deviation of 1.10 and a posttest mean of 2.93 with a standard deviation of 0.42. The difference between the pretest and posttest mean for pupils exposed to the experimental group was 2.45. On the other hand, the pretest mean of pupils exposed to pictorials (control group) was 0.44 with a standard deviation of 1.06 and a posttest mean of 1.35 with a standard deviation of 1.50. The difference between the pretest and posttest mean for pupils exposed to the control group was 0.91. From this result, it implies that pupils exposed to tactile instructional strategy (experimental group) performed better than those exposed to pictorials (control group) in their identification of letter Bb.

Hypothesis One

There is no significant difference between the mean letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials.

Table 3: Analysis of Covariance (ANCOVA) of the mean difference in the mean letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials.

Source	Type III Sum of Squares	T	Mean Square	F	P-Value
Corrected model	96.957a	2	48.478	28.391	.000
Intercept	457.948	1	457.948	268.195	.000
Pretest	.241	1	.241	.141	.708
Strategies	95.944	1	95.944	56.189	.000
Error	326.136	191	1.708		
Total	1026.000	194			
Corrected total	432.093	193			

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a R Squared = .229 (Adjusted R Squared = .221)
Source: Field data (2025)

The result on Table 3 shows that an F-ratio of 56.189 with an associated probability value of0.000 was obtained with regards to the mean difference between the mean letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials. Since the associated probability of 0.000 was less than 0.05, the null hypothesis (HO1) which states that there is no significant difference between the mean letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials was rejected. This implies that there is a significant difference between the mean letter Aa identification performance of pupils taught using tactile instructional strategy and those taught using pictorials.

Hypothesis Two

There is no significant difference between the mean letter Bb identification performance of pupils taught using tactile instructional strategy and those taught using pictorials.

Table 4: Analysis of Covariance (ANCOVA) of the mean difference in the identification performance of pupils taught using tactile instructional strategy and those taught using pictorials.

Source	Type III Sum of Squares	Df	Mean Square	F	P-Value
Corrected model	121.254a	2	60.627	50.463	.000
Intercept	757.214	1	757.214	630.275	.000
Pretest	6.576	1	6.576	.000	.994
Strategies	121.210	1	121.210	100.892	.000
Error	229.468	191	1.201		
Total	1260.000	194			
Corrected total	350.722	193			

a R Squared = .346 (Adjusted R Squared = .339)
Source: Field data (2025)

The result in Table 4 shows that an F-ratio of 100.891 with an associated probability value of 0.000 was obtained with regards to the mean difference between the mean letter Bb identification performance of pupils taught using tactile instructional strategy and those taught using pictorials. Since the associated probability of 0.000 was less than 0.05, the null hypothesis (HO2) which states that there is no significant difference between the mean letter Bb identification performance of pupils taught using tactile instructional strategy and those taught using pictorials was rejected. This implies that there is a significant difference between the mean letter Bb identification performance of pupils taught using tactile instructional strategy and those taught using pictorials.

Summary of Findings

The purpose of this study was to investigate the effect of tactile instructional strategy on pupils' acquisition of letter identification skills in Ikom education zone. The following were major findings of the study:

1. There is a significant difference between the mean letter Aa identification performance of pupils taught using tactile strategy and those taught using pictorials
2. There is a significant difference between the mean letter Bb identification performance of pupils taught using tactile instructional strategy and those taught using pictorials

Discussion of Findings

Hypothesis one indicated a significant difference between the mean letter Aa identification scores of pupils using tactile instructional strategy and those taught using pictorials. By this, the first null

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hypothesis which states that there is no significant difference between the mean letter Aa identification scores of pupils taught using tactile instructional strategy and those taught using pictorials is rejected. This result was possible because pupils taught using tactile instructional strategy (experimental group) had higher mean gain on letter Aa identification scores, while those taught with the pictorials (control group) had less mean gain on letter Aa identification scores. This finding is in agreement with the work of Hosack (2016) who conducted a study on the effects of hands-on instructional strategies on fourth grade pupils' attitudes and performance in number work in Florida. Hosack found that the use of hands-on instructional strategy decreased pupils' number work anxiety, pupils, number work attitude improved using hands-on instructional strategy, improve the performance of pupils. He also found that pupils expressed a great deal of enthusiasm in making use of manipulative that is touching and working with hands. Also, the finding of this study is not in line with the findings of white (2022) who conducted a study on the effect of an instructional model, utilizing hands-on learning and manipulations on Mathematics achievement of middle school pupils in Georgia. He found out that there were no significant differences between the post-test scores of the average-achieving mathematics pupils in control group and the average achieving number work pupils in the experimental group. Hypothesis two showed a significant difference between the mean letter Bb identification scores of pupils taught using tactile instructional strategy and those taught using pictorials. By this, the null hypothesis which states that there is no significant difference between the mean letter Bb identification scores of pupils taught using tactile instructional strategy and those taught using pictorials is rejected. This result was possible because pupils taught using tactile instructional strategy (experimental group) had higher mean gain on letter Bb identification scores. This finding is in line with Donna (2024) who conducted a study on the effect of inquiry-based, hands-on learning on achievement in middle school science in Lynchburg and found that there was no significant difference in student achievement. Similarly, it corroborates the findings of Ekwueme, Ekom and Ezenwa-Nebife (2015) who in a study affirmed that hands-on approach performed significantly better than those exposed to conventional method in Mathematics and Basic Science; it also showed that students preferred hands-on approach (activity-oriented to conventional (pen and paper) method.

Conclusion

Early skills in alphabetic serve as strong predictors of reading success, while later deficits in alphabetic is the main source of reading difficulties. It is observed that most of our children cannot identify letter. This disturbing phenomenon is not without its many negative implications especially given the fact that letter identification correlates reading and writing achievement. The slow and poor performances of preschoolers in letter identification have been attributed to the use of conventional instructional methods, and poor strategies by instructors. From the findings of this study, it can be concluded that the tactile instructional strategy was found to be effective in improving pupils' acquisition of letter skills. It was also concluded from the findings of this study that there was a significant effect of tactile instructional strategy on pupils' acquisition of letter identification skills. This implies that this strategy is effective in re-dressing the issue of pupils' difficulties in letter identification in Ikom education Zone of Cross River State, Nigeria

Recommendations

On the basis of the findings of this study, the researchers therefore make the following recommendation:

1. Since this study has revealed the effectiveness of tactile instructional strategy, teachers should integrate tactile instructional strategy into teaching letter identification in the classroom.

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2. Institution responsible for teacher preparation in early childhood education, should incorporate the use of tactile instructional strategy into their curriculum so as to equip the pre-service teachers the competencies needed in the use of this strategy.
3. State Ministries of education Boards and relevant professional associations interested in improving the literacy problems of the younger generations, should organize workshops and in-service training for teachers to make them conversant with the proper and regular use of tactile instructional strategy.

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Influence of Parental Educational Status on Attitude and Performance in Mathematics among Senior Secondary School Students in Katsina State, Nigeria

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Abstract
This study examined the influence of parental educational status on senior secondary school students' attitude and performance in Mathematics in Katsina State, Nigeria. The study adopted an ex-post facto survey research design. The population comprised 215,370 senior secondary school students in public secondary schools in Katsina State, from which a sample of 382 students was selected using multistage sampling. Data were collected using the Attitude towards Mathematics Questionnaire (ATMQ) and a Students' End-of-Term Result Sheet to collect students' performance. The ATMQ had a Cronbach's Alpha reliability coefficient of 0.88. Data collected were analysed using simple linear regression at the 0.05 level of significance. The findings revealed that parental educational status significantly influenced students' attitude towards Mathematics, $F(1, 380) = 66.842$, $p < .05$, with an R^2 of .127, indicating that parental educational status explained 12.7% of the variance in students' attitude. Similarly, parental educational status significantly influenced students' performance in Mathematics, $F(1, 380) = 64.171$, $p < .05$, with an R^2 of .138, indicating that parental educational status accounted for 13.8% of the variance in students' performance. The study concluded that parental educational status is a significant factor associated with students' attitude and performance in Mathematics. It was recommended that educational stakeholders strengthen parental involvement, school–home collaboration, and academic support programmes to assist parents in supporting their children's learning of Mathematics, irrespective of their educational background.

Keywords: Parental Educational Status, Students' Attitude and Mathematics Performance.

Introduction
Mathematics is an important subject in the Nigerian educational system because it contributes to the development of logical reasoning, problem-solving abilities, quantitative skills, and scientific thinking. It is also relevant to students' progression into science, technology, engineering, economics, education, and other fields of study. Despite the importance of Mathematics, students' achievement in the subject remains a concern in Nigeria, making it necessary to examine the factors that may influence students' learning outcomes. Recent Nigerian research has continued to identify factors associated with students' achievement in Mathematics, including parental and home-related variables (Adeleke et al., 2024). Students' performance in Mathematics is influenced by a combination of school, individual, and family factors. These include teachers' instructional practices, availability of learning resources, students' motivation, learning environment, parental involvement, and socioeconomic and educational background. Among these factors, parental educational status is particularly important because the educational experiences of parents may shape the nature and extent of support they provide for their children's schooling. Adeleke et al. (2024), for example, found a significant relationship between parental qualification and children's Mathematics achievement among students in Oyo State, Nigeria. Parental educational status refers to the highest level of formal education attained by a student's parent or parents. It may range from no formal education to primary, secondary, and tertiary education. Differences in parents' educational attainment may influence their knowledge of school requirements, educational expectations, ability to assist with schoolwork, and capacity to provide learning materials and other forms of academic support. Parents

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with higher educational qualifications may have greater familiarity with the educational system and may therefore be more capable of supporting their children's academic activities. However, parental educational status alone does not determine students' educational performance, as other family, school, and individual factors also contribute to learning.

Students' attitude toward Mathematics is another important consideration in understanding their performance in the subject. Attitude encompasses students' feelings, beliefs, interest, confidence, and disposition toward Mathematics. Students who develop positive attitudes may demonstrate greater interest in Mathematics, participate actively in classroom activities, and persist when faced with challenging mathematical tasks. Conversely, negative attitudes may be associated with reduced interest, avoidance of mathematical activities, and reluctance to engage with difficult problems. Therefore, understanding factors that may contribute to students' attitudes toward Mathematics is important for improving both engagement and achievement. Parental educational status may influence students' attitudes toward Mathematics through parental expectations, encouragement, academic guidance, and involvement in learning. Parents with higher educational attainment may be more likely to recognize the importance of Mathematics and encourage their children to develop positive attitudes toward the subject. They may also monitor schoolwork, communicate with teachers, provide learning resources, and establish expectations concerning academic achievement. However, the influence of parental education may also depend on the extent to which parents actively participate in their children's education. Adeleke et al. (2024) reported that parent-teacher partnership attitude partially mediated the relationship between parental qualification and children's Mathematics achievement, suggesting that parental educational qualification may operate partly through parents' engagement with the school.

The relationship between parental educational status and students' Mathematics performance has also received attention in Nigerian educational research. Evidence from studies conducted in Nigeria indicates that parental educational attainment can be associated with students' Mathematics outcomes. For instance, Salaudeen and Azeez (2022) reported that parental educational attainment significantly affected pupils' performance in Mathematics in selected primary schools in Zaria Local Government Area of Kaduna State. Similarly, Adeleke et al. (2024) found that parental qualification had a significant direct relationship with children's Mathematics achievement in Oyo State. These findings suggest that parents' educational background may be an important family-related factor in students' Mathematics achievement. Parental educational status is an important family-related factor associated with students' Mathematics achievement (Adeleke et al., 2024; Salaudeen & Azeez, 2022). The influence of parental educational status is particularly relevant in the Nigerian context because students come from families with diverse educational backgrounds. Some parents have no formal education, while others have attained primary, secondary, or tertiary education. These differences may affect the educational resources, academic guidance, expectations, and learning support available to students (Claudine, 2023). Nevertheless, students from families with lower parental educational attainment can also achieve highly when they receive appropriate support from teachers, schools, parents, and other educational stakeholders. Therefore, parental educational status should be examined as one of several factors that may contribute to students' educational outcomes rather than as the sole determinant of achievement (Adeleke et al., 2024).

In Katsina State, understanding the influence of parental educational status is important because students attend schools within diverse family and socioeconomic environments. Differences in

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parents' educational backgrounds may be reflected in the level of academic support and guidance students receive outside the classroom. Such differences may potentially influence students' attitudes toward Mathematics and their performance in the subject (Adeleke et al., 2024; Claudine, 2023). However, findings from other Nigerian states may not necessarily reflect the situation among senior secondary school students in Katsina State because educational and family contexts vary across locations. This makes context-specific research necessary to establish the extent to which parental educational status is associated with students' Mathematics outcomes in Katsina State. Although previous Nigerian studies have examined parental qualification, parental involvement, and other family-related variables in relation to Mathematics achievement (Adeleke et al., 2024; Salaudeen & Azeez, 2022), there is a need for further empirical evidence focusing specifically on the influence of parental educational status on students' attitude toward and performance in Mathematics among senior secondary school students in Katsina State. Examining both attitude and performance is important because students' disposition toward Mathematics may influence their engagement with the subject, while academic performance reflects their measurable learning outcomes. Therefore, this study investigates the influence of parental educational status on senior secondary school students' attitude toward and performance in Mathematics in Katsina State, Nigeria.

Statement of the Problem

Mathematics is a core subject in Nigerian secondary schools and is essential for developing students' logical reasoning, problem-solving abilities, and quantitative skills. Despite its importance, students' attitude towards and performance in Mathematics continue to be a concern to educational stakeholders. Negative attitudes, including low interest, lack of confidence, and reluctance to engage in mathematical activities, may affect students' participation and academic outcomes (Adeleke et al., 2024). This situation calls for greater attention to the factors that may influence students' attitude and performance in Mathematics. One factor that may be associated with students' Mathematics outcomes is parental educational status. Parents differ in their levels of educational attainment, and such differences may affect their capacity to provide academic guidance, monitor schoolwork, assist with learning activities, provide educational resources, and encourage their children to learn Mathematics. Evidence from previous studies indicates that parental educational qualification is significantly associated with students' Mathematics achievement (Adeleke et al., 2024; Salaudeen & Azeez, 2022). However, parental educational status should not be regarded as the sole determinant of students' outcomes, since students' attitude and performance may also be influenced by school, teacher, peer, and individual factors. Although previous studies have examined the relationship between parental educational background and students' academic achievement, limited empirical evidence is available on the influence of parental educational status on both students' attitude towards and performance in Mathematics among senior secondary school students in Katsina State. Furthermore, findings obtained from other geographical locations may not adequately reflect the educational and family circumstances of students in Katsina State. This creates a need for context-specific evidence on the extent to which parental educational status is associated with students' Mathematics outcomes in the State. Therefore, the problem addressed by this study is the insufficient empirical evidence on the influence of parental educational status on senior secondary school students' attitude towards and performance in Mathematics in Katsina State, Nigeria. The study consequently examined the influence of parental educational status on students' attitude towards and performance in Mathematics in the State.

Research Objectives

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The objective of this study were to:

1. determine the influence of parental educational status on senior secondary school students' attitude toward Mathematics in Katsina State, Nigeria.
2. examine the influence of parental educational status on senior secondary school students' performance in Mathematics in Katsina State, Nigeria.

Null Hypotheses

The following null hypotheses were tested at .05 level of significance.

1. There is no significant influence of parental educational status on senior secondary school student attitude toward mathematics in Katsina State, Nigeria
2. There is no significant influence of parental educational status on senior secondary school student performance in mathematics in Katsina State, Nigeria

Significance

The findings of this study are expected to be useful to students, parents, teachers, school administrators, educational planners, and researchers. The study may help teachers understand how parental educational status relates to students' attitude and performance in Mathematics, thereby supporting the adoption of appropriate strategies for students from different family backgrounds. Parents may also gain greater awareness of the importance of providing academic support and encouragement to their children irrespective of their educational attainment. School administrators and educational planners may use the findings to develop programmes that strengthen parental involvement and improve students' learning outcomes in Mathematics. The study may also provide empirical evidence for educational policymakers in planning interventions aimed at improving Mathematics education. Finally, the findings may serve as a reference for researchers interested in parental educational status, students' attitude, and academic performance in Mathematics.

Research Methodology

Research Design

The study adopted an ex-post facto survey research design. The design was considered appropriate because the variables under investigation already existed and could not be manipulated by the researcher. The design enabled the researcher to examine the influence of parental educational status on students' attitude toward and performance in Mathematics.

Population and Sample

The population comprised 215,370 senior secondary school students in 261 public senior secondary schools across the 34 Local Government Areas of Katsina State. A sample of 382 students, comprising 224 males and 158 females, was selected using the Krejcie and Morgan (1970) sample size determination table. A multistage sampling technique involving stratified, purposive, and simple random sampling was used to select the participants from 30 public senior secondary schools across the three senatorial zones of the State.

Instrumentation

Data were collected using the Attitude towards Mathematics Questionnaire (ATMQ) and a Proforma (Students' End-of-Term Result Sheet). The ATMQ consisted of Section A, which collected students' background information and parental educational status (no formal education, primary, secondary, and tertiary education), and Section B, which comprised 20 items measuring students' attitude toward Mathematics on a four-point Likert scale. The Proforma was used to obtain students' Mathematics scores from official school records.

Validity and Reliability

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Experts in Mathematics Education, Measurement and Evaluation, and Educational Psychology subjected the instruments to face and content validation. A pilot study involving 30 SS II students from a school outside the sampled schools was conducted. The ATMQ yielded a Cronbach's Alpha reliability coefficient of 0.88, indicating satisfactory internal consistency.

Data Collection and Analysis

Data were collected by the researcher with the assistance of trained research assistants after obtaining the necessary permission from the relevant authorities and school principals. The completed questionnaires were retrieved immediately after administration, while students' Mathematics scores were obtained from official school records. Data were coded and analysed using SPSS Version 23. Percentages were used for descriptive analysis, while regression analysis was used to test the hypotheses at the 0.05 level of significance.

Data Analysis

The data collected were coded and analysed using the Statistical Package for the Social Sciences (SPSS) Version 23. Simple linear regression analysis was employed to test the two null hypotheses at the 0.05 level of significance.

Presentation of Results

Research Hypotheses

The hypotheses formulated for the study were tested using simple linear regression analysis. The null hypothesis was rejected whenever the p-value was less than the alpha level of 0.05; otherwise, it was retained.

Hypothesis One: There is no significant influence of parental educational status on senior secondary school students' attitude toward mathematics in Katsina State, Nigeria

Table 1: *linear Regression Analysis Summary Table Showing the Relative influence of parental educational status on senior secondary school students' attitude toward mathematics*

R = **.356**
R Square =**.127**
Adjusted R Square = **.125**
Std. Error of the Estimate = **12.41857**

Model	Sum of Squares	Df	Mean Square	F-value	Sig.
Regression	10312.445	1	10312.445		
Residual	71123.754	380	187.168	66.842	.000
Total	81436.199	381			

Table 1 reveals that the independent variable significantly influenced the dependent variable among the respondents ($F_{1, 381} = 66.842$; $p < 0.05$). Therefore, the null hypothesis is rejected. This means that there is a significant influence of the independent variable on the dependent variable among the respondents. The findings further imply that the independent variable is a significant predictor of the dependent variable among the respondents, contributing 12.7% to the total variance in the dependent variable ($R^2 = .127$).

Hypothesis Two: There is no significant influence of parental educational status on senior secondary school students' performance in mathematics in Katsina State, Nigeria.

Table 2: *Linear Regression Analysis Summary Table Showing the Relative influence of parental educational status on senior secondary school students' performance in mathematics*

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R = **.372**
R Square **=.138**
Adjusted R Square = **-.136**
Std. Error of the Estimate = **13.12741**

Model	Sum of Squares	Df	Mean Square	F-value	Sig.
Regression	11056.742	1	11056.742		
Residual	68960.644	380	181.954	64.171	.000
Total	80017.386	381			

Table 2 reveals that the independent variable significantly influenced the dependent variable among the respondents ($F_{1,380}$ = 64.171; $p < 0.05$). Therefore, the null hypothesis is rejected. This means that there is a significant influence of the independent variable on the dependent variable among the respondents. The findings further imply that the independent variable is a significant predictor of the dependent variable among the respondents, contributing 13.8% to the total variance in the dependent variable (R^2 = .138).

Summary of the Findings

The summary of the major findings of the study are:

1. There is significant influence of parental educational status on senior secondary school student attitude toward mathematics in Katsina State, Nigeria
2. There is significant influence of parental educational status on senior secondary school student performance toward mathematics in Katsina State, Nigeria

Discussion of Findings

The finding in hypothesis two showed that there is significant influence of parental educational status on senior secondary school students' attitude toward Mathematics in Katsina State, Nigeria. The result indicated that parental educational status significantly influenced students' attitude toward Mathematics. This finding supports Claudine (2023) and Caixin and Yumeng (2023), who established that parents with higher educational qualifications tend to provide stronger academic support and expectations that positively influence students' attitudes toward learning. The finding implies that educated parents are more likely to guide, motivate, and create a conducive learning environment for their children, thereby improving students' attitude toward Mathematics. However, the result contradicts Adigun (2023), who reported that parents' education has no significant influence on students' academic attitude and performance. The finding in hypothesis four showed that there is significant influence of parental educational status on senior secondary school students' performance in Mathematics in Katsina State, Nigeria. The result indicated that parental educational status significantly influenced students' performance in Mathematics. This finding agrees with Atolagbe, Oparinde and Umaru (2019), Claudine (2023), and Uwaonye and Ben (2021), who found that parents' educational attainment positively influences students' academic performance by creating enabling learning conditions and academic support. The finding suggests that educated parents are more likely to assist with academic activities, monitor learning progress, and encourage effective study habits that improve students' performance in Mathematics. However, the result disagrees with Adigun (2023), who argued that parental education has no significant effect on students' academic achievement.

Conclusion

Based on the findings in this study, the following conclusions were made:

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From the findings of this study, the study concluded that there are significant influences of parental educational status on senior secondary school students' attitude and performance in Mathematics in Katsina State, Nigeria.

This implies that when students receive adequate parental support arising from favourable educational status, their interest, attitude, and performance in Mathematics are likely to improve.

Recommendations

Based on the findings and conclusion drawn, the researcher recommends the following:

1. The Katsina State Ministry of Education and other educational stakeholders should intensify sensitization, adult literacy, and continuing education programmes to improve parents' educational awareness and capacity to provide adequate academic guidance, encouragement, and support for their children's learning of Mathematics.
2. Schools should establish effective school–home collaboration and parent-support programmes involving teachers, counsellors, and parents to help parents with different educational backgrounds understand how to guide, monitor, and support their children, thereby promoting positive attitudes towards Mathematics.
3. Schools and relevant educational stakeholders should provide adequate academic support, including remedial Mathematics lessons, mentoring, instructional materials, guidance, and counselling, particularly for students whose parents may have limited educational capacity to support their learning, in order to improve their attitude and performance in Mathematics.

Contribution to Knowledge

The study has made the following contributions to knowledge:

1. The study provides empirical evidence that parental educational status significantly influences both senior secondary school students' attitude towards Mathematics and their performance in Mathematics in Katsina State, Nigeria. This contributes to existing knowledge by demonstrating that parents' level of educational attainment is an important factor associated with students' Mathematics learning outcomes.
2. The study contributes context-specific evidence on the relationship between parental educational status and Mathematics outcomes among senior secondary school students in Katsina State. The findings provide useful information for educational planners, policymakers, school administrators, counsellors, parents, and researchers in understanding the importance of parental educational background in supporting students' positive attitudes and improved performance in Mathematics.
3. The study provides a foundation for further research by highlighting the need to examine other factors that may influence students' attitude and performance in Mathematics, including parental involvement, parenting style, family size, socio-economic status, teacher effectiveness, school facilities, classroom environment, peer influence, and students' motivation. It also provides a basis for comparative studies across different locations, subjects, and parental groups.

Suggestions for Further Studies

The following suggestions were made:

1. Future studies should be conducted in other States and geo-political zones of Nigeria and across other school subjects, such as English Language, Biology, Chemistry, and Physics, to determine whether similar findings would be obtained regarding the influence of parental educational status on students' attitude and academic performance.

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2. Further studies should employ longitudinal designs and examine other family-related variables, such as parental involvement, parenting style, family size, socio-economic status, and household income, to provide a broader understanding of factors influencing students' attitude and performance in Mathematics.
3. Future researchers should separately examine the educational status of fathers and mothers and also investigate school- and learner-related factors, such as teacher effectiveness, school facilities, classroom environment, peer influence, and students' motivation, to provide deeper and broader evidence on factors influencing students' attitude and performance in Mathematics.

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Teachers' Awareness on Edulastic Application for Sustainable and Inclusive STEM Education in Basic Science Curriculum Content Delivery in Sabon Tasha, Kaduna State, Nigeria

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Abstract

The study evaluated Sustainable and Inclusive STEM Education and Research of Teachers' awareness and use of edulastic application for curriculum content delivery in Sabon Tasha education zone. The study adopted descriptive survey research design. The population for the study comprised all the teachers in the six senior secondary schools in the Area Council. The sample for the study was made up of 96 teachers conveniently selected from four senior secondary schools (2021/2022) academic session. The instrument for data collection was developed by the researchers titled: "Level of Awareness, Use and Constraints of Edulastic Application Questionnaire (LAUCEAQ)". The instrument was pilot tested on 10 senior secondary school teachers not covered in the study. Cronbach Alpha was employed to determine its reliability coefficient that yielded r=.89. The instrument was administered on the respondents by the researchers and a 100% return rate was achieved. Data collected were analyzed using frequency counts, percentages and mean set values of 2.50 – 3.00, 1.51-2.49 and 0.50 - 1.50 representing high, moderate and low extents respectively. Findings revealed teachers' low level of awareness and use of edulastic application. Among the constraints encountered by the senior secondary teachers include: lack of awareness, poor supply of electricity, low or weak network/bandwidth and non-integration of technology in the subject curricula.

Keywords: Edulastic Application, Awareness, Sustainable, Inclusive.

Introduction

Teaching and Learning in the 21st century have taken a digital dimension. It is no longer business as usual where the teachers and the students are expected to come face-to-face. The activities of teaching and learning can and now takes place anywhere and at any point in time. The activities hold outside the conventional classroom (Otemuyiwa, 2020). Classes for teacher and learners can be held online and can also be simultaneous. The conduct of classes for the delivery of curriculum content to take place is made easy and possible with the use of Information and Communication Technology (ICT) resources with combination of educational applications such as Animoto, Class-Marker, Edmodo, Edulastic, Flipgrid, Google Classroom, Socrative, Quizalize, Quizziz and so on to mention but few. The engagement of the aforementioned requires the use of internet connection. This can be referred to as educational programme which Katkukah and Okoyefi, (2018) sees as educational process where most of the teaching is carried out by someone not within the place of the learners to the point that communication between the teacher and learners is by an artificial medium.

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STEM education encompassing science, technology, engineering, and mathematics has become a pivotal driver of sustainable development worldwide. In developing nations like Nigeria, its significance is increasingly acknowledged due to its potential to address multifaceted challenges, such as climate change, economic disparities, and rapid technological advancements. By fostering critical thinking, problem-solving abilities, and innovation, STEM education equips learners to navigate and mitigate these issues effectively. According to UNESCO (2022), STEM education is instrumental in achieving the Sustainable Development Goals (SDGs), particularly those related to quality education, gender equality, and economic growth. Nigeria's commitment to STEM education is evident in initiatives such as the establishment of federal universities of science and technology, aimed at strengthening STEM teaching and learning (Federal Ministry of Education, 2023). However, persistent challenges remain, including inadequate funding, limited employability skills among graduates, low research output, and insufficient teacher capacity (Okebukola, 2021).

Inclusive STEM education is essential for Nigeria's future, as it equips young people with the skills required for participation in a rapidly evolving global economy and empowers them to contribute meaningfully to sustainable development. STEM education supports economic growth by fostering job creation, innovation, and entrepreneurship. With Nigeria's youth unemployment rate estimated at over 33% (National Bureau of Statistics, 2021), STEM education has been identified as a critical pathway for preparing students for highdemand careers and promoting innovation-led economic diversification in line with national development goals (Okebukola, 2021). Miller, Nwaekete and Akiti (2016) accounted that online teaching and learning are educational activities for the delivery of curriculum content through either email, internet, DVD, CD-Rom, videotape and other social media channels. The use of these resources is subject to awareness and ability to use such resource by both the teacher and the learners. A classroom can be created with Edulastic application using www.edulastic.com. Learners can be invited into the platform (Otemuyiwa, 2020). Subsequent interaction can continue by the teacher assigning duties to members in the platform. As easy as it is to operate in this platform, the place of awareness is very important. The place Awareness in the use of any of the educational platform cannot be over-emphasized. Awareness is an important factor which proceeds the use. Taiwo, (2009) defined awareness as knowledge about a phenomenon. Lack of awareness can and thus obstructs use. Doris, 2012 noted that, as a rule of awareness, one has to be severally exposed to a phenomenon before awareness of same can be achieved. Several studies have been conducted on teachers' awareness ICT resources and application for teaching and learning. A study was carried out by Okolo, (2018) comparing public and private school teachers' awareness of ICT resources for teaching and learning. The study reported that teachers in both public and private senior secondary schools possessed high level of awareness. In the same vein, Oresanya, (2018) conducted a study on the awareness of junior school teachers on ICT resources for teaching and learning in Kwali Area Counci, Abuja. The study reported that the teachers possessed high level of awareness. Similarly, the study by Sulaiman, Hindatu and Lawal, (2017) on awareness of teachers on the use of ICT resources for teaching and learning in Matazu Local Government Area of Katsina State reported high level of awareness. However, the study conducted by Otemuyiwa, (2016) on public senior secondary school teachers' awareness of the use of mobile phone applications for teaching and learning in Kwali Area Council, Abuja reported a very low level of awareness by the teachers.

The use of ICT and its related gadgets in the delivery of curriculum content by teachers for students' learning involves various digital tools that enables the conduct of teaching and learning exercises without necessarily bringing together the teacher and the learners. This could be online with the use

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of the various educational applications. The level of use could be low, moderate or high. The study by Otemuyiwa, (2016) on senior secondary school teachers' use of mobile phone applications for teaching and learning in Kwali area council, FCT, Abuja indicated that mobile phone applications were not used by the teachers for teaching. The use of ICT resources and online educational applications such as quizalize, google classroom and edulastic among others is not without constraints. The associated constraints include: poor electricity supply, weak internet connection were some of the constraints faced by the teachers. The study by Otemuyiwa, (2020) that poor electricity supply for charging technical gadgets, absence of technology integration into subject curricula and non-provision of internet or slow bandwidth connectivity by school authority and lack of training for the teachers on the use of technologies. Likewise, the study by Otemuyiwa and Attah, (2019) submitted that epileptic power supply, poor ICT policy/project implementation, lack of skills by the teachers and limited access to the internet among others are among constraints confronting the use of most ICT based teaching and learning resources.

Theoretical and Conceptual Framework

This study is based on the Schema theoretical and Conceptual framewor. It shows that the study is on the respondents' use of the edulastic applications for the delivery of curriculum contents. The schema also reveals that the gender and qualifications of the respondents may have or influence the level of awareness of the respondents. (Aina, Ariyibi, Njoku, 2019).

Statement of the Problem

In the world over, the delivery of curriculum content to learners by teachers sustainable and inclusive education has been an age long activity in the process of teaching and learning. With the invention of technology which has cut across almost all aspects of human endeavor with no exception to education. It has become necessary at all levels of educational system especially at the junior secondary school level to introduce and use technology in teaching and learning. With the use of technological applications such as edulastic, teaching and learning can be easily conducted without the necessarily coming together of the teacher and learners. Situations like natural disaster in the form of flood and/or pandemic, where the coming together of the teacher and the learners are made difficult, the use of technological application can be leverage upon to carry out the activities like teaching and learning, conduct of continuous assessment, carry out examination and every other necessary communications between the teacher and the learners. However, teachers who are to engage in its use has to possess some level of awareness of the edulastic application for the delivery of curriculum in the junior secondary schools in Sabon Tasha local Government Area.

Purpose of the Study

The main purpose of this study was to determine the level of Sustainable and inclusive stem education of teachers' awareness and use of edulastic application for curriculum content delivery in Sabon Tasha education zone. Specifically, the objectives were to:

1. determine sustainable and inclusive stem education of junior school teachers' level of awareness of edulastic application for the delivery of curriculum content in Sabon Tasha education zone
2. examine the level of use of edulastic application by Sustainable and inclusive stem education of junior school teachers for the delivery of curriculum content
3. investigate the constraints encountered by the Sustainable and inclusive stem education of junior school teachers in the use of edulastic application in the delivery of curriculum content in Sabon Tasha education zone.

Research Questions

The following research questions were raised to guide the study and were answered:

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1. What is the Sustainable and inclusive stem education of junior school teachers' level of awareness of edulastic application for the delivery of curriculum content in Sabon Tasha education zone?
2. What is the level of use of edulastic application by Sustainable and inclusive stem education and research of junior school teachers in the delivery of curriculum content in Sabon Tasha education zone?
3. What are the constraints encountered by the Sustainable and inclusive stem education of junior school teachers in the use of edulastic application for the delivery of curriculum content in Sabon Tasha education zone?

Research Hypotheses

Ho_1: There is no significant difference between the level of Sustainable and inclusive stem education of awareness by male and female respondents of edulastic application for the delivery of curriculum content in education zone.

Ho_2: There is no significant difference on the level of use by respondents based on respondents' qualification of edulastic application for the delivery of curriculum content in Sabon Tasha education zone.

Research Methodology

This study adopted descriptive research design to evaluate sustainable and inclusive stem education of teachers' awareness and use of edulastic application in junior secondary school, use and constraints encountered in edulastic application in the delivery of curriculum content in Sabon Tasha Education Zone of Kaduna. The population for the study comprised all the teachers in the six senior secondary schools in the Area Council. The sample for the study was made up of ninety-six (96) teachers selected through convenient sampling method in four junior secondary schools (Kilankwa, Kwali, Pai and Yangoji) in the (2021/2022) academic session. A self- designed instrument designed by the researchers and edited by three each of experts in educational technology and measurement and evaluation; their comments were used by the researchers to further enrich the instrument. The instrument was titled: "Level of Awareness, Use and Constraints of Edulastic Application Questionnaire (LAUCEAQ)". The instrument was pilot tested on 10 senior secondary school teachers not covered in this study. Cronbach Alpha was then employed to determine its reliability coefficient which yielded r=.89. The instrument (96 copes) were administered on the respondents by the researchers and a 100% return rate was achieved. Data collected were analyzed using frequency counts, percentages and mean set values of 2.50 – 3.00, 1.51-2.49 and 0.50-1.50 representing high, moderate and low extents respectively. The three questions that guided the study were answered and the two hypotheses tested at 0.05 level of significance using chi square.

Table 1: Range of Scores

S/N	Ranges of Scores	Assigned definition
1	0-50 – 1.50	Low Level
2	1.51 – 2.50	Moderate Level
3	2.51 – 3.00	High Level

The information in Table 1, on range of scores indicate that 0.50 – 1.50 is assigned low level, 1.51 – 2.50 is indicated with moderate level while 2.51 – 3.00 is assigned with high level.

Table 2: Respondents' Profile

Gender	Frequency	Percentage
Male	52	54.17
Female	44	45.83
Total	**96**	**100**

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Qualifications	Frequency	Percentage
Degree & Equivalent	64	66.7
Master's Degree	32	33.3
Total	**96**	**100**

The data in the first segment of Table 2 is on the respondents' gender with frequency of 52 representing 54.17% and the female frequency of 44 representing 45.83. Frequency of both respondents of 96 and is 100%. The second segment of Table 2 is on the frequency and percentage of the respondents' qualification. Those with first degree and equivalent is 64 representing 66.7% and Master's degree 32 and represented 33.3%.

Presentation of Results

Research Question 1: What is the junior secondary school teachers' level of awareness of edulastic application for the delivery of curriculum content inSabon Tasha local Government Area?
To answer research question 1, Table 3 presents the results:

Table 3: Junior Secondary School Teachers' Level of Awareness of Edulastic Application for the delivery of Curriculum content in Sabon Tasha local Government Area

S/N	Items	M	SD
1.	I have heard about edulastic application as an educational application.	1.26	0.78
2.	I know that edulastic application is a free online educational application.	2.02	0.74
3.	I know that edulastic application can be used for teaching and learning.	1.48	0.79
4.	I am conversant with edulastic application as an educational application.	1.45	0.67
5.	I have the knowledge that edulastic application can be engaged in the conduct of continuous assessment for students.	2.01	0.72
6.	I have the understanding that edulastic application can be used for the conduct of examination for students.	1.61	0.73
7.	I know that edulastic application can be used as a means of communication between the teacher and the students.	1.59	0.89
8.	I know that edulastic application is user friendly	1.33	0.74
9.	I know that the various functions in the edulastic application are well integrated.	1.14	0.80
10.	I know that students' performance can be easily monitored with edulastic application.	1.21	0.81
	Overall Mean	**1.35**	

M = Mean, SD = Standard Deviation

The data presented in Table 3 on junior secondary school teachers' level of awareness of edulastic application for the delivery of curriculum content shows mean values that ranged between 1.14 and 2.02 with overall mean of 1.35. This signified that, the teachers' level of awareness of edulastic application for the delivery of curriculum content is low.

Research Question 2: What is the level of use of edulastic application by junior secondary school teachers in the delivery of curriculum content in Sabon Tasha local Government Area?
To answer research question 2, Table 4 presents the results:

Table 4: Level of Use of Edulastic Application for Curriculum Content Delivery by

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Junior Secondary School Teachers in Sabon Tasha local Government Area

S/N	Items	M	SD
1.	I use edulastic application to access prompt feedback from students.	1.13	0.79
2.	I use edulastic application to access students' data.	1.34	0.68
3.	I use edulastic application to easily monitor students' performance.	1.42	0.77
4.	I use edulastic application access students' displayed responses graphically.	1.57	0.87
5.	I save students' responses to questions using edulastic application.	1.47	0.69
6.	I access students' responses at any time.	1.55	0.78
7.	I use edulastic application to promptly detect incorrect responses given by students.	1.39	0.79
8.	I use edulastic application to access individual students' activities.	1.12	0.69
9.	I use edulastic application for scoring students' activities.	1.17	0.86
10.	I ask the students questions using edulastic application.	1.28	0.76
	Overall Mean	**1.34**	

M = Mean, SD = Standard Deviation

The result as shown in Table 4 on junior secondary school teachers' level of use of edulastic application for the delivery of curriculum content shows mean values that ranged between 1.12 and 1.57 with overall mean of 1.34. This showed that the teachers' level of use of edulastic application for the delivery of curriculum content is also low.

Research Question 3: What are the constraints encountered by the Sustainable and inclusive stem education and research of junior secondary school teachers in the use of edulastic application for the delivery of curriculum content in Sabon Tasha local Government Area?

To answer research question 3, Table 5 presents the results:

Table 5: Constraints Encountered by the Junior Secondary School Teachers for the delivery of Curriculum Content in Sabon Tasha local Government Area

S/N	Items	F	%
1	Teachers' lack of awareness of the use of edulastic application for teaching and learning.	72	75
2	Teachers' lack of knowledge to use edulastic application for teaching and learning.	77	80.2
3	Teachers' inability to teach subject area effectively using edulastic application.	79	82.3
4	Teachers not having interest to use edulastic application.	28	29.2
5	Teachers' negative attitude towards the use of edulastic application.	35	36.5
6	Lack of teachers' readiness to use edulastic application in teaching	34	35.4
7	Lack of training for teachers in the use of technology (edulastic)	78	81.3
8	Non provision of internet or slow bandwidth connectivity by the school authority.	81	84.
9	Absence of technology integration into subject curricula.	84	87.5

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10	Poor electricity supply for charging technology gadgets.	87	90.6

F = Frequency, % = Percentage

From the results presented in Table 5 on the constraints inhibiting the use of edulastic application by junior secondary school teachers in the delivery of curriculum content in Sabon Tasha Education Zone of Kaduna it is shown Poor electricity supply for charging technical gadgets, absence of technology integration into subject curricula and non-provision of internet or slow bandwidth connectivity by school authority and lack of trainings for the teachers on the use of technologies with 87 = 90.6%, 84 = 87.5%, 81 = 84.4% and 78 = 81.3% respectively were among the major constraints.

Hypothesis 1: There is no significant difference between the level of awareness by male and female respondents of edulastic application for the delivery of curriculum content in Sabon Tasha local Government Area.

Table 6: 2 x 3 Contingency Table on the Level of Male and Female Teachers Awareness of Edulastic Application for the delivery of curriculum content

Gender	Level of Awareness			Total
	High	Moderate	Low	
Male	O = 5 (E = 6.5)	O = 8 (E = 10.33)	O = 39 (E = 34.66)	**52**
Female	O = 7 (E = 5.5)	O = 12 (E = 9.17)	O = 25 (E = 29.33)	**44**
Total	**12**	**20**	**64**	**96**

O is Observed; E is Expected.

Table 6A: Chi-Square analysis on the level of Male and Female Teachers' Awareness of Edulastic Application for the delivery of Curriculum content

Df	Calculated Chi	Table Chi
94	2.094	5.991

Table 6A revealed that calculated chi is 2.094 at 94 df while the table chi is 5.991. Since the table chi is greater than the calculated, it implies that there is no statistically significant difference between male and female teachers in the level of awareness of the use of edulastic application for the delivery of curriculum content. Therefore, the null hypothesis which stated that "there is no significance difference between the level of awareness possessed by male and female senior secondary school teachers on edulastic application in the delivery of curriculum content is accepted.

Hypothesis 2: There is no significant difference on the level of awareness by respondents based on qualifications in edulastic application for the delivery of curriculum content in Sabon Tasha local Government Area

Table 7: 2 x 3 Contingency Table on the Respondents' Level of Awareness of Edulastic Application for the delivery of curriculum content based on Qualifications

Qualifications	Level of Awareness			Total
	High	Moderate	Low	
Degree & Equivalent	O = 4 (E = 8.40)	O = 6 (E = 11.63)	O = 52 (E = 41.98)	**62**
Masters' Degree	O = 9 (E = 4.60)	O = 12 (E = 6.38)	O = 13 (E = 23.02)	**34**

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Total	**13**	**18**	**65**	**96**

O is Observed; E is Expected.

Table 7A: Chi-Square analysis on the level of Respondents' Awareness of Edulastic Application for the delivery of Curriculum content based on Qualifications

Df	Calculated Chi	Table Chi
94	12.214	5.991

The result as shown in Table 7A, revealed the calculated chi of 12.214 with df 94 while the table chi is 5.991. Since the calculated chi is greater than the value of the table chi, the implication is that, the hypothesis which stated that "there is no significant difference between the levels of awareness of the junior secondary school teachers on the use of edulastic application for the delivery of curriculum contents on the basis of the respondents qualifications is rejected.

Discussion of Findings

The result of the analysis in Table 3 shows that the level of the junior secondary school teachers' awareness of edulastic application for the delivery of curriculum content which stood at 1.35 signifying low level. It should be noted that awareness precedes utilization. In this digital age in the 21st century, the delivery of curriculum content has passed the era of face-to-face method. The low level of teachers' awareness as revealed in this study is in agreement with the study by Otemuyiwa, (2016) on public junior secondary school teachers' awareness of the use of mobile phone applications for teaching and learning in Sabon Tasha local Government Area. The study reported a very low level of awareness by the teachers. Similarly, the result is in line with the study by Imoniwe (2018), that students' level of awareness of search engine was low. In the same vein, the findings of this study is in conformity with the study by Otemuyiwa and Moyinoluwa (2021) that, business studies teachers in Gwagwalada Area Council of Abuja possessed little awareness level of ICT resources for teaching and learning. The result from the analysed data on the level of use of edulastic application for delivery of curriculum contents in junior secondary school in Sabon Tasha local Government Area revealed a low level. This result is not surprising as the teachers' level of awareness was equally low. It should be noted that, awareness precedes use. If the level of teachers' awareness is high, it will impact on the level of use. It will be out of place for level of awareness of a phenomenon to be low and its level of use to be otherwise. What a teacher is not aware of, will not be expected to be put to use by the same teacher. The finding from this study disagrees with the report by Otemuyiwa, (2016) that, junior secondary school teachers' level of awareness on the use of mobile phone application for teaching in Sabon Tasha local Government Area on the basis of gender. The data presented in table 5 revealed the respondents' stand on the constraints on the use of edulastic application for the delivery of curriculum content in Sabon Tasha local Government Area. The result affirmed that there were some challenges which include but not limited to the following: teachers' lack of awareness, poor electricity supply for charging technical gadgets, absence of technology integration into subject curricula and non-provision of internet or slow bandwidth connectivity by school authority and lack of trainings for the teachers on the use of technologies. This finding is in line with the earlier findings reported by CETIN, (2018) and Onasanya, Otemuyiwa and Onasanya (2020) that the poor electricity supply, weak internet connections were some of the constraints though not major. This finding also agreed with the report by Otemuyiwa, 2020 that poor electricity supply for charging technical gadgets, absence of technology integration into subject curricula and non-provision of internet or slow bandwidth connectivity by school authority and lack of trainings for the teachers on the use of technologies. The result of the data analysed in Tables 6 and 6A showed that there was no significant

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difference on the level of awareness of the teachers on the use of edulastic application for the delivery of curriculum content in junior secondary school in Sabon Tasha local Government Area. The finding implies that, the teachers' gender did not have significant effect on the senior secondary school teachers' level of awareness on the use of mobile phone applications for teaching and learning in Sabon Tasha local Government Area based on gender. This finding is not in consonant with an earlier report by Otemuyiwa, (2016) that senior secondary school teachers' gender did not have significant effect on their level of awareness. The analysis of the hypothesis as presented in Tables 7 and 7A revealed that there was significant difference on the teachers' qualification on awareness of edulastic application for the delivery of curriculum content in senior secondary schools in Sabon Tasha local Government Area. This finding is not in agreement with the earlier finding reported by Otemuyiwa, (2016) where it was submitted that the junior secondary school teachers' qualifications had no significant difference(s) on their level of awareness on the use of mobile phone applications for teaching in senior secondary schools in Sabon Tasha local Government Area.

Conclusion

This study revealed that the junior secondary school teachers had low level of awareness on the use of edulastic application for the delivery of curriculum contents in Sabon Tasha local Government Area. The study also showed that the teachers had low level of the use of edulastic application. This is not unconnected to the fact that the teachers' low level of awareness will definitely lead to low level of use. The study also revealed that, teachers' gender did not have significant difference in their responses. However, the respondents' level of qualification had significant difference on their level of awareness. The more qualified teachers are the more awareness they will have. On the constraints responsible for the teachers' use of edulastic application for the delivery of curriculum content; poor electricity supply for powering technology gadgets, absence of technology integration into subject curricula, non-provision of internet or slow bandwidth connectivity by school authority and teachers' inability to teach subject area effectively using edulastic application among others in the delivery of curriculum content in junior secondary schools in Sabon Tasha local Government Area.

Recommendations

Based on the findings of this study, the following recommendations were made:

1. The Nigerian Educational Research and Development Council (NERDC) should endeavor to explore and incorporate educational technologies in the schools' curricula for implementation.
2. The Junior Secondary Education Board in Sabon Tasha local Government Area should endeavor to organize trainings for the teachers on the integration of educational technologies in teaching and learning.
3. The Junior secondary school teachers in Sabon Tasha local Government Area should endeavor to take it upon themselves to individually update their knowledge on the use of educational application for teaching and learning.
4. The Kaduna South Electricity Distribution Company in the local Government Area should step up on the level of power supply in the Area.
5. Budgetary allocation should be available for the teachers for procuring data for internet connectivity.

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Correlation between Teachers' Pedagogical Competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State, Nigeria

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Abstract

This study investigated the relationship between teachers' pedagogical competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State, Nigeria. A correlational survey research design was adopted. The population comprised 6,735 Senior Secondary II students in public secondary schools in Bayelsa State, from which a sample of 250 students was selected using the simple random sampling technique. Data were collected using a researcher-developed instrument titled Teachers' Pedagogical Competence and Mathematics Problem-Solving Skills Questionnaire (TPCMPSQ). The instrument was validated by experts in Mathematics Education and Measurement and Evaluation, while its reliability was established using Cronbach's Alpha, yielding an overall reliability coefficient of 0.84. Pearson Product Moment Correlation (PPMC) was used to answer the research questions and test hypotheses at the 0.05 level of significance. The findings revealed significant relationships between teachers' instructional strategies, classroom management competence, assessment competence, communication competence, and students' problem-solving skills in Mathematics. The study concluded that teachers' pedagogical competence is a significant predictor of students' problem-solving skills in Mathematics. It was therefore recommended that educational stakeholders should strengthen continuous professional development programmes for Mathematics teachers to enhance their pedagogical competence and improve students' problem-solving abilities.

Keywords: Pedagogical competence, instructional strategies, mathematics problem-solving skills, schools

Introduction

Mathematics is universally recognized as a fundamental discipline for scientific inquiry, technological innovation, economic growth, and sustainable national development. It equips learners with logical reasoning, quantitative thinking, analytical skills, and the capacity to solve real-life problems. Consequently, Mathematics occupies a central position in Nigeria's educational system and is compulsory at the basic and secondary school levels. The objectives of Mathematics education extend beyond computational proficiency to include the development of critical thinking, creativity, and problem-solving competencies that enable learners to function effectively in an increasingly knowledge-driven society (Federal Republic of Nigeria [FRN], 2014). Despite its importance, students' achievement in Mathematics in Nigerian secondary schools has remained a major concern among educators, parents, policymakers, and examination bodies. The persistent poor performance of students in public examinations such as the West African Senior School Certificate Examination (WASSCE) and the National Examinations Council (NECO) has been attributed to several factors, including inadequate instructional practices, ineffective teaching methods, poor classroom management, limited use of learner-centred instructional approaches, and insufficient pedagogical competence among Mathematics teachers (Oribhabor, 2020; Paul et al., 2026).

One of the major goals of Mathematics education is the development of students' problem-solving skills. Problem-solving is regarded as the ability to analyse unfamiliar situations, identify relevant mathematical concepts, formulate solution strategies, implement appropriate procedures, evaluate

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solutions, and communicate mathematical reasoning effectively. It represents a higher-order cognitive process that enables learners to apply mathematical knowledge to practical situations rather than merely recalling formulas or performing routine calculations. Contemporary Mathematics curricula therefore emphasize problem-solving as a core competency necessary for academic success and lifelong learning (Chapman, 2015; Lit, Kool, & Drijvers, 2026). The successful development of students' mathematical problem-solving skills depends largely on the competence of the teacher. Teachers serve as facilitators who design meaningful learning experiences, guide classroom interactions, diagnose students' misconceptions, provide constructive feedback, and create learning environments that encourage critical thinking and independent reasoning. Consequently, improving students' mathematical problem-solving abilities requires teachers who possess not only adequate subject matter knowledge but also sound pedagogical competence (Shulman, 1986, 1987; Chapman, 2015).

Pedagogical competence refers to the knowledge, skills, attitudes, and professional practices that enable teachers to facilitate effective learning. It encompasses lesson planning, instructional delivery, classroom management, learner engagement, assessment practices, communication skills, use of instructional resources, and the ability to adapt teaching strategies to learners' diverse needs. Teachers with high pedagogical competence employ learner-centred instructional strategies that actively engage students in mathematical inquiry, collaboration, exploration, and reflective thinking rather than relying solely on teacher-centred exposition (Shulman, 1987; Sonmark et al., 2017). Shulman (1986, 1987) introduced the concept of pedagogical content knowledge (PCK), emphasizing that effective teaching requires more than mastery of subject matter. According to Shulman, teachers must possess specialized knowledge that enables them to transform complex concepts into forms that are understandable to learners through appropriate explanations, analogies, demonstrations, examples, and representations. In Mathematics education, pedagogical competence enables teachers to anticipate students' misconceptions, select suitable instructional strategies, scaffold learning, and create opportunities for students to develop conceptual understanding and problem-solving proficiency.

In Bayelsa State, successive governments and educational stakeholders have implemented various initiatives aimed at improving the quality of Mathematics education through teacher recruitment, curriculum implementation, capacity-building programmes, and professional development workshops. Despite these efforts, students' performance in Mathematics has remained relatively unsatisfactory in many public senior secondary schools. Researchers have attributed this trend to factors such as inadequate teacher preparation, insufficient pedagogical training, limited integration of innovative teaching strategies, inadequate instructional resources, and weak classroom assessment practices (Oribhabor, 2020). Although numerous studies have investigated teacher effectiveness and students' academic achievement, relatively few have specifically examined the relationship between teachers' pedagogical competence and students' mathematical problem-solving skills among senior secondary schools in Bayelsa State. Most previous studies have focused primarily on students' achievement scores without adequately exploring higher-order cognitive outcomes such as mathematical reasoning, critical thinking, and problem-solving competence. This gap limits the availability of context-specific evidence needed by policymakers, school administrators, and teacher education institutions to strengthen Mathematics instruction within the state. It is against this background that this study investigates the relationship between teachers' pedagogical competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State, Nigeria.

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Statement of the Problem

Mathematics plays a pivotal role in fostering scientific literacy, technological innovation, and economic development. Consequently, the acquisition of mathematical problem-solving skills has become one of the primary goals of Mathematics education globally and in Nigeria. Problem-solving skills enable students to apply mathematical concepts to unfamiliar situations, think critically, make logical decisions, and solve real-life problems. Despite the emphasis placed on problem-solving in the Nigerian Senior Secondary School Mathematics Curriculum, many students continue to demonstrate poor proficiency in solving non-routine mathematical problems, as reflected in their performance in internal and external examinations.

Reports from the West African Examinations Council (WAEC) over the years have consistently shown that a substantial proportion of candidates fail to obtain credit passes in Mathematics, with examiners repeatedly identifying weaknesses in students' reasoning, analytical thinking, and application of mathematical concepts to solve problems. These weaknesses have raised concerns among educators, curriculum planners, and policymakers regarding the effectiveness of Mathematics instruction in Nigerian secondary schools. Although several factors have been associated with students' poor performance in Mathematics, increasing attention has been directed toward teacher-related factors, particularly pedagogical competence, because teachers remain the principal facilitators of learning within the classroom.

In Bayelsa State, government and educational stakeholders have invested in teacher recruitment, curriculum implementation, and professional development programmes aimed at improving the quality of Mathematics education. Nevertheless, students' performance in Mathematics has remained unsatisfactory in many senior secondary schools. Available studies in the state have largely focused on students' academic achievement, instructional materials, ICT integration, or teachers' subject matter knowledge, while relatively little empirical attention has been given to how teachers' pedagogical competence influences students' mathematical problem-solving skills. This creates a significant knowledge gap, especially considering that the ability to solve mathematical problems is a key indicator of meaningful learning and an essential competency for the twenty-first century.

Therefore, the problem of this study is to investigate the relationship between teachers' pedagogical competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State, Nigeria.

Aim and Objectives of the Study

The aim of this study is to investigate the relationship between teachers' pedagogical competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State, Nigeria. Specifically, the study seeks to:

1. Determine the relationship between teachers' instructional strategies and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.
2. Examine the relationship between teachers' classroom management competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.
3. Find out the relationship between teachers' assessment competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.
4. Investigate the relationship between teachers' communication competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.

Research Questions

The following research questions guided the study:

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1. What is the relationship between teachers' instructional strategies and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State?
2. What is the relationship between teachers' classroom management competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State?
3. What is the relationship between teachers' assessment competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State?
4. What is the relationship between teachers' communication competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State?

Null Hypotheses

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

1. There is no significant relationship between teachers' instructional strategies and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.
2. There is no significant relationship between teachers' classroom management competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.
3. There is no significant relationship between teachers' assessment competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.
4. There is no significant relationship between teachers' communication competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.

Review of Related Literature

Students' Problem-Solving Skills in Mathematics

Problem-solving in Mathematics refers to the cognitive process through which learners identify, analyse, and resolve mathematical tasks for which no immediate solution method is apparent. It involves understanding the problem, selecting appropriate mathematical concepts and procedures, implementing suitable strategies, evaluating the correctness of solutions, and communicating the reasoning behind the solution (Polya, 1945 in OECD, 2023). According to Polya (1945), effective mathematical problem-solving follows four systematic stages: understanding the problem, devising a plan, carrying out the plan, and looking back to evaluate the solution. These stages continue to provide the foundation for teaching mathematical problem-solving in classrooms worldwide.

The National Council of Teachers of Mathematics (NCTM, 2018) defines mathematical problem-solving as the process of applying previously acquired mathematical knowledge, skills, and reasoning to solve unfamiliar and meaningful problems. The NCTM further identifies problem-solving as one of the five fundamental process standards that should guide Mathematics teaching and learning, alongside reasoning and proof, communication, connections, and representation. This perspective emphasizes that students should not merely memorize mathematical procedures but should develop the capacity to think critically, reason logically, and apply mathematics creatively in different contexts. Similarly, Schoenfeld (2016) describes mathematical problem-solving as a complex intellectual activity that integrates conceptual understanding, strategic competence, procedural fluency, adaptive reasoning, and productive disposition. According to Schoenfeld, successful problem solvers possess the ability to monitor their thinking, select appropriate strategies, evaluate alternative solutions, and modify their approaches whenever necessary. These competencies enable learners to become independent thinkers capable of solving increasingly complex mathematical problems. The development of mathematical problem-solving skills depends on several instructional and learner-related factors. Among these, teachers' pedagogical competence plays a central role

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because teachers create the learning experiences through which students develop reasoning and analytical abilities. Effective Mathematics teachers employ learner-centred instructional strategies such as inquiry-based learning, problem-based learning, cooperative learning, mathematical investigations, and classroom discussions that actively engage students in solving authentic mathematical problems (Chapman, 2015). These instructional approaches encourage students to explore multiple solution methods, justify their reasoning, and construct mathematical knowledge through active participation.

Teachers' Pedagogical Competence

Teachers' pedagogical competence is widely recognized as one of the most important determinants of effective teaching and students' academic success. It refers to the knowledge, skills, attitudes, and professional practices that enable teachers to facilitate meaningful learning by employing appropriate instructional methods, managing classroom activities effectively, assessing learners' progress, and creating conducive learning environments. Pedagogical competence goes beyond mastery of subject content; it encompasses the ability to transform content knowledge into meaningful learning experiences that accommodate learners' diverse abilities, interests, and needs (Shulman, 1987). The Organisation for Economic Co-operation and Development (OECD, 2020) defines teachers' pedagogical competence as the ability to design, implement, and evaluate instructional activities that promote students' cognitive, affective, and psychomotor development. This competence includes planning effective lessons, employing learner-centred instructional strategies, managing classroom interactions, utilizing assessment information to improve instruction, integrating technology into teaching, and engaging students actively in the learning process. Similarly, the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2019) views pedagogical competence as a combination of professional knowledge, instructional skills, ethical values, and reflective practices that enable teachers to facilitate inclusive, equitable, and quality education. Teachers who possess these competencies are better equipped to foster students' critical thinking, creativity, collaboration, and problem-solving skills. In Mathematics education, pedagogical competence assumes even greater significance because Mathematics is characterized by abstract concepts, symbolic representations, logical reasoning, and problem-solving activities. Effective Mathematics teachers must therefore possess the pedagogical skills required to simplify abstract concepts, promote conceptual understanding, encourage mathematical reasoning, and develop learners' confidence in solving mathematical problems. Chapman (2015) argued that teachers' pedagogical competence determines their ability to facilitate mathematical problem-solving through questioning techniques, guided discovery, classroom discourse, and scaffolding strategies that enable students to construct mathematical knowledge independently.

Contemporary educational reforms have increasingly emphasized learner-centred pedagogy as a hallmark of pedagogical competence. Learner-centred teaching shifts the focus from teacher-directed instruction to active student participation in knowledge construction. Professional development plays a vital role in strengthening teachers' pedagogical competence. Continuous professional learning enables teachers to update their instructional knowledge, acquire innovative teaching strategies, improve assessment practices, and respond to curriculum reforms. Darling-Hammond et al. (2017) maintained that sustained professional development significantly enhances teachers' instructional practices and positively influences students' academic achievement. Teachers who participate regularly in workshops, seminars, mentoring programmes, and professional learning communities are more likely to adopt evidence-based instructional practices that improve students' learning outcomes. Within the Nigerian educational context, pedagogical competence has become

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increasingly important due to the implementation of competency-based curricula and the growing emphasis on developing twenty-first-century skills. The National Policy on Education (Federal Republic of Nigeria [FRN], 2014) emphasizes that teachers should employ innovative teaching methods that promote creativity, critical thinking, communication, collaboration, and problem-solving. However, studies conducted in Nigeria have reported that many Mathematics teachers continue to rely predominantly on traditional lecture methods, limiting students' opportunities to develop higher-order thinking and problem-solving skills (Oribhabor, 2020; Ukeje et al., 2019).

Theoretical Review

Shulman's Theory of Pedagogical Content Knowledge (PCK)

This study is anchored on Shulman's Theory of Pedagogical Content Knowledge (PCK) developed by Lee S. Shulman (1986, 1987). The theory emphasizes that effective teaching requires more than mastery of subject matter; it involves the integration of content knowledge with appropriate pedagogical skills that enable teachers to present concepts in ways that are understandable to learners. According to Shulman (1986), pedagogical content knowledge is the unique combination of subject matter knowledge and teaching strategies that enables teachers to transform complex concepts into meaningful learning experiences. Teachers with strong pedagogical content knowledge are able to select appropriate instructional methods, use relevant examples and illustrations, anticipate students' misconceptions, and employ suitable assessment techniques to enhance learning. Shulman (1987) further explained that effective teachers possess several categories of knowledge, including content knowledge, general pedagogical knowledge, curriculum knowledge, knowledge of learners, and pedagogical content knowledge. Among these, pedagogical content knowledge is considered the most important because it distinguishes professional teachers from individuals who simply possess subject matter expertise. The theory is relevant to this study because the independent variable, teachers' pedagogical competence, reflects the principles of pedagogical content knowledge. Specifically, instructional strategies, classroom management, assessment competence, and communication competence are essential components of effective pedagogy that influence students' learning. It is therefore expected that Mathematics teachers with higher pedagogical competence will be better able to develop students' problem-solving skills.

Constructivist Learning Theory

The study is also underpinned by the Constructivist Learning Theory, developed by Jean Piaget (1972) and further advanced by Lev Vygotsky (1978). The theory posits that learners actively construct knowledge through interaction with their environment rather than passively receiving information from the teacher. Learning occurs when students engage in meaningful activities, explore ideas, solve problems, and connect new knowledge with their prior experiences. Piaget (1972) emphasized that learners construct knowledge through cognitive processes of assimilation and accommodation. According to him, meaningful learning occurs when students actively participate in learning tasks that challenge their existing understanding and enable them to develop higher levels of thinking. In Mathematics, students develop problem-solving skills by exploring mathematical concepts, analysing situations, and discovering relationships through active engagement. Vygotsky (1978) extended the theory by emphasizing the importance of social interaction in learning. He introduced the concept of the Zone of Proximal Development (ZPD), which refers to the gap between what learners can accomplish independently and what they can achieve with guidance from a more knowledgeable person, such as a teacher or peer. Vygotsky argued that effective teaching involves providing appropriate support, or scaffolding, to help learners gradually develop independent problem-solving abilities.

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The Constructivist Learning Theory is relevant to this study because it emphasizes learner-centred instruction, active participation, collaboration, and guided discovery, which are essential components of effective pedagogical competence. Mathematics teachers who employ inquiry-based learning, problem-based learning, classroom discussions, and collaborative activities create opportunities for students to develop critical thinking and mathematical problem-solving skills. Therefore, the theory supports the view that teachers' pedagogical competence significantly influences students' ability to solve mathematical problems. It provides a suitable theoretical basis for explaining how effective instructional strategies, classroom management, assessment, and communication can enhance students' problem-solving skills in Mathematics.

Empirical Review

Chapman (2015) investigated Mathematics teachers' knowledge for teaching problem-solving through a qualitative review of studies conducted in different educational settings. The study found that teachers with strong pedagogical content knowledge effectively guided students through problem-solving processes by employing questioning techniques, scaffolding, collaborative learning, and reflective discussions. The study concluded that teachers' pedagogical competence significantly enhances students' conceptual understanding and problem-solving abilities. Chapman recommended continuous professional development programmes to strengthen teachers' pedagogical skills for effective Mathematics instruction.

Depaepe, Verschaffel, and Kelchtermans (2013) conducted a systematic review of research on pedagogical content knowledge in Mathematics education. The review synthesized findings from numerous empirical studies and reported that teachers' pedagogical content knowledge positively influences students' mathematical understanding, reasoning, and achievement. The authors observed that teachers who effectively combine subject matter knowledge with appropriate pedagogical strategies create learning environments that promote conceptual understanding and higher-order thinking. They recommended that teacher education programmes should place greater emphasis on developing pedagogical content knowledge alongside subject matter competence. Oribhabor (2020) investigated the effect of activity-based instructional methods on secondary school students' achievement in Mathematics using a quasi-experimental research design. The study involved senior secondary school students who were taught using activity-based and conventional teaching methods. The findings revealed that students exposed to activity-based instruction performed significantly better than those taught using traditional lecture methods. The study concluded that learner-centred instructional strategies, which are important indicators of pedagogical competence, improve students' conceptual understanding and problem-solving skills in Mathematics. Paul et al. (2026) examined the effect of Polya's problem-solving instructional strategy on students' achievement and retention in Mathematics among senior secondary school students in Akwa Ibom State, Nigeria. Using a quasi-experimental design, the researchers found that students taught through Polya's problem-solving model achieved significantly higher scores and demonstrated better retention than students taught using conventional teaching approaches. The study concluded that effective pedagogical strategies that emphasize guided problem-solving significantly enhance students' mathematical reasoning and academic performance.

Research Methodology

The study adopted a correlational survey research design. The choice of this design was informed by the nature of the study, which sought to determine the relationship between teachers' pedagogical competence and students' problem-solving skills in Mathematics without manipulating the variables. Correlational research design is appropriate for establishing the degree and direction of relationship

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among naturally occurring variables (Bhandari, 2021). The population of the study consists 6,735 senior secondary II (SS II) students in public secondary schools in Bayelsa State, Nigeria. A sample size of 250 Senior Secondary II students was selected from the population using the simple random sampling technique. The instrument for data collection was a self-designed questionnaire titled: **"**Teachers' Pedagogical Competence and Mathematics Problem-Solving Skills Questionnaire (TPCMPSQ)**"** using the modified 4-point Likert scale of Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). Face and content validity were used in this study. Experts in measurement and evaluation examined the items on the instrument and confirmed that they were adequate and suitable for the study. To determine the reliability of the instruments, a pilot study was conducted among 30 Senior Secondary II students from public secondary schools outside the sampled schools but with similar characteristics. The data obtained were analyzed using the Cronbach's Alpha reliability method, which yielded reliability coefficients of 0.84, indicating that the instrument was reliable for the study. Data used in this study were collected through the administration of the questionnaire to senior secondary school students in the selected public secondary schools in Bayelsa State. Pearson Product Moment Correlation was used to answer the research questions and test the hypotheses at 0.05 level of significance.

Presentation of Results

Research Question One: What is the relationship between teachers' instructional strategies and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State?

Hypothesis One: There is no significant relationship between teachers' instructional strategies and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.

Table 1: Pearson Product Correlation Coefficient Table Showing the Relationship Between Teachers' Instructional Strategies and Students' Problem-Solving Skills in Mathematics among Senior Secondary Schools in Bayelsa State

		Teachers' Instructional Strategies	Problem-Solving Skills
Teachers' Instructional Strategies	Pearson product moment Correlation	1	0.682
	Significant 2-tailed		0.000
	N	250	250
Problem-Solving Skills	Pearson Correlation	0.682	1
	Sig. (2-tailed)	0.000	
	N	250	250

** Correlation is significant at the 0.01 level (2-tailed).

Table 1 shows that there is high positive relationship between teachers' instructional strategies and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State (r= 0.682). When tested for significant difference, the significant 2-tailed was 0.000 which is lower than the acceptable alpha level of 0.05. Therefore, the null hypothesis is rejected, implying that there is significant relationship between teachers' instructional strategies and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.

Research Question Two: What is the relationship between teachers' classroom management competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State?

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Hypothesis Two: There is no significant relationship between teachers' classroom management competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.

Table 2: Pearson Product Correlation Coefficient Table Showing the Relationship Between Teachers' Classroom Management Competence and Students' Problem-Solving Skills in Mathematics among Senior Secondary Schools in Bayelsa State

		Teachers' Classroom Management Competence	Problem-Solving Skills
Teachers' Classroom Management Competence	Pearson product moment Correlation	1	0.615
	Significant 2-tailed		0.000
	N	250	250
Problem-Solving Skills	Pearson Correlation	0.615	1
	Sig. (2-tailed)	0.000	
	N	250	250

** Correlation is significant at the 0.01 level (2-tailed).

Table 2 shows that there is high positive relationship between teachers' classroom management competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State (r= 0.615). When tested for significant difference, the significant 2-tailed was 0.000 which is lower than the acceptable alpha level of 0.05. Therefore, the null hypothesis is rejected, implying that there is significant relationship between teachers' classroom management competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.

Research Question Three: What is the relationship between teachers' assessment competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State?

Hypothesis Three: There is no significant relationship between teachers' assessment competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.

Table 3: Pearson Product Correlation Coefficient Table Showing the Relationship Between Teachers' Assessment Competence and Students' Problem-Solving Skills in Mathematics among Senior Secondary Schools in Bayelsa State

		Teachers' Assessment Competence	Problem-Solving Skills
Teachers' Assessment Competence	Pearson product moment Correlation	1	0.653
	Significant 2-tailed		0.000
	N	250	250
Problem-Solving Skills	Pearson Correlation	0.653	1
	Sig. (2-tailed)	0.000	
	N	250	250

** Correlation is significant at the 0.01 level (2-tailed).

Table 3 shows that there is high positive relationship between teachers' assessment competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State

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(r= 0.653). When tested for significant difference, the significant 2-tailed was 0.000 which is lower than the acceptable alpha level of 0.05. Therefore, the null hypothesis is rejected, implying that there is significant relationship between teachers' assessment competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.

Research Question Four: What is the relationship between teachers' communication competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State?

Hypothesis Four: There is no significant relationship between teachers' communication competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.

Table 4: Pearson Product Correlation Coefficient Table Showing the Relationship Between Teachers' Communication Competence and Students' Problem-Solving Skills in Mathematics among Senior Secondary Schools in Bayelsa State

		Teachers' Communication Competence	Problem-Solving Skills
Teachers' Communication Competence	Pearson product moment Correlation	1	0.704
	Significant 2-tailed		0.000
	N	250	250
Problem-Solving Skills	Pearson Correlation	0.704	1
	Sig. (2-tailed)	0.000	
	N	250	250

** Correlation is significant at the 0.01 level (2-tailed).

Table 4 shows that there is moderate positive relationship between teachers' communication competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State (r= 0.704). When tested for significant difference, the significant 2-tailed was 0.000 which is lower than the acceptable alpha level of 0.05. Therefore, the null hypothesis is rejected, implying that there is significant relationship between teachers' communication competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State.

Discussion of Findings

The findings presented in Table 1 show that there is high positive relationship between teachers' instructional strategies and students' problem-solving skills in Mathematics among senior secondary school students in Bayelsa State, and the null hypothesis was rejected. This implies that the instructional strategies employed by Mathematics teachers significantly influence students' ability to solve mathematical problems. Teachers who adopt learner-centred instructional approaches such as problem-based learning, inquiry-based learning and guided discovery are more likely to develop students' critical thinking and problem-solving skills than those who rely solely on conventional lecture methods. This finding is consistent with the study of Chapman (2015), who reported that teachers' pedagogical knowledge and instructional strategies significantly enhance students' mathematical reasoning and problem-solving abilities. The finding also agrees with Oribhabor (2020), who found that activity-based instructional methods significantly improved students' achievement and problem-solving skills in Mathematics.

The findings presented in Table 2 reveal that there is high positive relationship between teachers' classroom management competence and students' problem-solving skills in Mathematics among

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senior secondary school students in Bayelsa State, and the null hypothesis was rejected. This implies that effective classroom management creates a conducive learning environment where students actively participate in classroom activities, collaborate with peers, and confidently engage in mathematical problem-solving tasks. This finding corroborates the work of Emmer and Sabornie (2015), who observed that effective classroom management positively influences students' engagement, motivation, and academic achievement. It is also in agreement with Hattie (2023), who identified classroom environment and teacher effectiveness as major determinants of students' learning outcomes. The findings in Table 3 indicate that there is high positive relationship between teachers' assessment competence and students' problem-solving skills in Mathematics among senior secondary school students in Bayelsa State, and the null hypothesis was rejected. This implies that teachers who employ appropriate assessment techniques, monitor students' learning progress, and provide timely and constructive feedback contribute significantly to the development of students' mathematical problem-solving abilities. This finding supports the study of Black and Wiliam (2018), who reported that formative assessment and effective feedback significantly improve students' learning and academic performance. The finding also aligns with Shavelson (2010), who emphasized that assessment should be integrated into the teaching-learning process to enhance students' understanding and problem-solving competence.

The findings presented in Table 4 show that there is a significant relationship between teachers' communication competence and students' problem-solving skills in Mathematics among senior secondary school students in Bayelsa State, and the null hypothesis was rejected. This indicates that teachers who communicate mathematical concepts clearly, encourage classroom discussions, ask thought-provoking questions, and provide meaningful explanations significantly enhance students' understanding and problem-solving skills. This finding agrees with Mercer and Dawes (2014), who found that productive classroom dialogue promotes reasoning, critical thinking, and collaborative learning. It also supports the findings of Chapman (2015), who concluded that effective teacher communication and classroom discourse are essential for developing students' mathematical problem-solving abilities.

Recommendations

Based on the findings of the study, the following recommendations are made:

1. Mathematics teachers should adopt learner-centred instructional strategies, such as problem-based learning, inquiry-based learning, and guided discovery, to enhance students' mathematical reasoning and problem-solving skills.
2. The Bayelsa State Ministry of Education and the Post Primary Schools Board (PPSB) should organize regular workshops, seminars, and in-service training programmes to improve Mathematics teachers' pedagogical competence.
3. School administrators should encourage effective classroom management practices by providing a conducive learning environment and monitoring teachers' instructional delivery to promote active student participation and engagement during Mathematics lessons.
4. Mathematics teachers should strengthen their assessment practices by using continuous formative assessment, providing timely and constructive feedback, and designing assessment tasks that emphasize critical thinking and problem-solving rather than rote memorization.

Conclusion

This study examined the relationship between teachers' pedagogical competence and students' problem-solving skills in Mathematics among senior secondary schools in Bayelsa State, Nigeria. The

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findings revealed that teachers' instructional strategies, classroom management competence, assessment competence, and communication competence each had significant positive relationships with students' problem-solving skills. The study reveals the importance of learner-centred instructional practices in fostering students' critical thinking, mathematical reasoning, and problem-solving abilities. Mathematics teachers who employ innovative teaching strategies, maintain conducive classroom environments, implement effective assessment practices, and communicate mathematical concepts clearly are more likely to develop students' confidence and competence in solving both routine and non-routine mathematical problems. Based on these findings, it is concluded that improving teachers' pedagogical competence is essential for enhancing the quality of Mathematics education and promoting students' problem-solving skills in senior secondary schools. Therefore, sustained investment in teacher professional development, continuous pedagogical training, and the adoption of evidence-based instructional practices will contribute significantly to improving students' performance in Mathematics and achieving the goals of mathematics education in Bayelsa State and Nigeria at large.

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Effects of Computer-Based Tutorial Instructional Strategy on Academic Achievement in Biology Among Senior Secondary School Students in Katsina State, Nigeria

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Abstract
The integration of computers in to teaching and learning science and technology has yielding positive results in improving the quality of education over the years in learning institutions across the globe. Studies have been on board to determine the efficacy and validity of this innovation as regards quality of teaching and learning in various learning institution yet with varied results. On this background, this study investigated the effects of a Computer-Based Tutorial Instructional Strategy (CBTIS) on academic achievement of Senior Secondary School students in Katsina State, Nigeria. A quasi-experimental design was adopted, precisely pre-test, post-test, non-equivalent control group design. The population comprised all Biology students across the 12 zones of the Science and Technical Education Board (STEB) and Ministry of Education in Katsina State. A sample size of 247 students was selected from four co-educational schools using multi-stage sampling. The instrument used for data collection was the Biology Achievement Test (BAT), validated by three experts with a split-half reliability coefficient of 0.85. Research questions were answered using mean and standard deviation, while hypotheses were tested at 0.05 level of significance using Independent Samples t-tests. Findings revealed that students exposed to the CBTIS achieved significantly higher post-test mean scores than those exposed to conventional lecture methods, t(245) = .55, p< 0.05. Conversely, gender exerted no significant effect on the academic achievement of students exposed to CBTIS t(123) = 0.031.55, p> 0.05. Based on these findings, it was concluded that CBTIS enhances student performance in Biology regardless of gender. It was recommended that Biology teachers in secondary schools in Katsina State Ministry should adopt CBTIS in teaching Biology

Keywords: Biology Education, Computer-Based Tutorial, Achievement, Biology, Students

Background of the Study

Science and Technology Education has been the driving force for scientific breakthrough and industrial advancement globally over a long period of time, Biology as a core science subject occupies a critical position as it bridges the gap between natural phenomena and applied sciences such as Medicine, Agriculture, and Biotechnology. Despite its foundational importance and high enrollment rates among senior secondary school students in Nigeria, the subject has been plagued by persistent low performance rates in external assessments like the West African Senior School Certificate

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Examination (WASSCE) and the National Examinations Council (NECO). This academic deficit is often tied to the continuous reliance on teacher-centered, conventional instructional strategies. The standard lecturing approach turns classrooms into passive environments where abstract biological concepts (e.g., cell division, genetics, nutrient cycles) are explained without interactive visual support. To counter this, modern educational frameworks emphasize student-centered, technology-driven pathways. Among these innovations, the computer-Based Tutorial (CBT) instructional strategy stands out. CBT uses interactive software to present self-paced lessons, break down complex concepts into dynamic steps, offer immediate electronic feedback, and provide remediation pathways based on student input (Fasha u &Omotayo,2024, Orji et al., 2026). In Katsina State, efforts by the State Government to distribute computers and establish digital laboratories across educational zones emphasize the regional drive for digital integration. However, the pedagogical application of these tools in classroom settings remains under-researched (Azih,et al 2022, Orji et al.,2026,) Furthermore, discussions regarding student outcomes must address gender parity. Examining whether technology-driven interventions benefit male and female students equally remains crucial for establishing equitable educational practices in the region.

Literature Review

Studies abound at local and international levels on the effects of CBT instructional strategies and different learning outcomes. The most reoccurring learning outcomes are academic achievement retention motivation attitudes, and interest. This study is mainly focusing on achievement and gender effect on the achievement. Empirical studies on this dimension appeared to be with differential findings, but mostly reported positive effects of CBT instructional strategy. For example, Azih *et al.* (2022) conducted a study on the computer-based programmed instructional study and tertiary students' achievement, using tertiary students in Nigeria and adopting quasi experimental research. From their findings, it appeared that CBIS enhanced learners' knowledge, motivation and classroom engagement during instruction. In another study by *Jean et al* (2022) on the impact of computer-assisted instruction on students' academic performance in Biology appeared another fact. The researchers adopted quasi experimental study using pretest posttest non randomized control group with 90 sampled senior secondary school students in Ngagatere. With a valid and reliable instrument of 0.70 coefficient data was generated. The findings revealed that there was significant difference between the performance of students taught biology with CBI and those taught with conventional teaching. Nebert (2023) studied effects of computer-based instruction on senior secondary school learners ' academic achievement in Biology using the same design and methodology. The result indicated a significant difference in performance in favour of the experimental group. In the same vein, Orji et al. (2026) studied the effects of computer-mediated strategy (CMIS) on students achievement and retention in Biology in Abuja Nigeria. The sample were 110 SS2 students, adopting quasi experimental design and generating data using valid and reliable Biology Achievement Test and treatment instruments. The results indicated that the students taught Biology with CMIS out-performed those taught with conventional method of teaching. In the same dimension, Fashanu and Omotayo (2026) investigated the effect of computer-based instructional strategy on students' learning outcomes in Biology among secondary schools in Ekiti state, Nigeria. Using a population of 12690, sample of 159 SS2 and Biology Performance Test, data was generated and analysed using t-test. The results indicated that students learned with computer- based instruction significantly performed better than those learned using conventional teaching strategy. From the reported empirical studies, there was no significant effect of gender on the students' learning outcomes (Azih et al., 2022, Jean et al. 2022, Orji et al. 2026, Fashanu &Omotayo 2026).

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By implication, it proved that CBTIS has been gender friendly in teaching and learning activities across various institutions of learning within and outside the nation.

Statement of the Problem

The academic output of senior secondary school students in Biology within Katsina State has fallen short of standard benchmarks in national exams (NECO, 2024, WAEC, 2024) Reports from local inspectors and educational boards consistently point to poor retention of abstract concepts, lack of student engagement, and instructional rigidity as key factors (Azih et al.,2026). The traditional lecturing style often fails to provide the multi-sensory experiences needed to master complex biological pathways. While computer networks and digital devices have been distributed to several public schools across Katsina State, they are often restricted to basic computer literacy classes. Their systematic use as direct teaching aids in core sciences like Biology is limited. There is also a lack of localized quantitative data detailing how computer-based tutorials affect student performance in the state. This study directly addresses this gap by investigating the impact of a structured Computer-Based Tutorial (CBT) instructional strategy on the academic achievement of Senior Secondary School Biology students in Katsina State.

Aim and Objectives of the Study

The aim of this study was to examine how a Computer-Based Tutorial Instructional Strategy (CBTIS) has effect on academic achievement in Biology among secondary school students in Katsina State. The specific objectives sought to:

1. compare the post-test academic achievement scores of Biology students taught using the CBT instructional strategy against those taught using the conventional instructional method.
2. assess the post-test academic achievement scores of male and female Biology students exposed to the CBT instructional strategy.

Research Questions

The following research questions were formulated as to achieve the stated objective of the study:

1. What is the difference in the post-test academic achievement mean scores between Biology students taught Biology with the Computer-Based Tutorial (CBTIS) strategy and those taught with the conventional instructional method?
2. What is the difference in the post-test academic mean achievement scores between male and female Biology students taught Biology with the CBT instructional strategy?

Null Hypothesis

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

$H_0$1: There is no significant difference between the post-test mean academic achievement scores of students taught Biology using the Computer-Based Tutorial Instructional Strategy and those taught using the conventional instructional method.

$H_0$2: There is no significant difference between the post-test mean academic achievement scores of male and female students taught Biology using the CBTIS

Research Methodology

Research Design:

This study adopted a quasi-experimental design, specifically, pre-test, post-test, non-equivalent control group design. This design is appropriate for educational settings because it allows researchers to study real-world classroom interventions without disrupting existing class groupings through random individual placement(Fraenkel,2019)

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Population of the study:

The target population comprised all senior secondary school year-two Biology students in public co-educational institutions across Katsina State. Records from the Ministry of Education indicated a total population of students taking Biology across the state's educational zones. The cohort was selected because their curriculum covers highly complex biological topics, and they are free from the immediate pressures of final external examinations.

Sample and Sampling Techniques:

The sample for this study consisted of senior secondary school students selected via a rigorous multi-stage sampling technique: Stage I (Purposive Sampling): Four distinct Educational Zones within Katsina State were chosen based on the availability of functional, solar-powered or grid-connected computer laboratories in their public schools; Stage II (Simple Random Sampling): One co-educational public senior secondary school was selected from each chosen zone, giving a number of four schools. Co-educational institutions were chosen to ensure gender representation within the same school environment. And Stage III (Cluster Sampling): In each selected school, one intact science class was assigned to either the Experimental Group or the Control Group via a coin toss. This resulted in two schools forming the experimental group(60 males, 65 female= 125) and two schools forming the control group(58 males, 64 females=122)

Research Instruments

The primary tool for data collection was the Biology Achievement Test (BAT), designed by the researcher based on the national senior secondary school curriculum. The BAT consisted of 50 multiple-choice questions covering topics such as *Cellular Respiration, Plant Nutrition, Excretory Systems,* and *Ecology*. Each item carried four options (A–D) worth one mark each, for a maximum score of 50. To ensure validity, the initial draft of 70 items was reviewed by two experts in Science Education and one psychometric expert from Umaru Musa Mai'adua University, Katsina. They evaluated content validity, language clarity, and alignment with curriculum benchmarks. Following their feedback, 20 items were removed or reworded, leaving a 50-item instrument. The BAT was pilot-tested on an intact class of 20 students in a school outside the main sample. Using the split-half reliability method paired with the Spearman-Brown prophecy formula, the instrument yielded a high internal consistency coefficient of 0.85, making it reliable for field research.

Two detailed operational frameworks were used during the study: The The Computer-Based Tutorial Instructional Strategy (CBTIS) Package**:** This interactive offline software program was installed on individual desktops in the school labs. It presented information in structural blocks, used animated diagrams to illustrate processes like mitosis and digestion, required students to answer checkpoint questions before advancing, and provided instant feedback with explanations. And the Conventional Lecture Framework: This traditional lesson plan relied on the blackboard and teacher-led explanations. The teacher delivered the exact same curriculum content over the same duration, using standard static textbook illustrations without digital interactivity. Before starting lessons, the pre-test BAT was administered to both groups by the researcher and trained research assistants to measure baseline knowledge. The experimental group then attended Biology classes in the computer laboratory using the CBTIS software, while the control group met in standard classrooms using traditional lectures. The study ran for four weeks across both groups. At the end of the intervention, the post-test BAT (with randomized question numbers to prevent memorization) was administered to all participants. The collected scripts were marked and compiled numerically. Research questions were analyzed using descriptive statistics, specifically Mean and Standard Deviation. Null hypotheses were tested using Independent Samples t-tests.

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Presentation of Results

Research Question 1

What is the difference in the post-test academic achievement mean scores between Biology students exposed to the computer-Based Tutorial Instructional Strategy and those exposed to the conventional instructional method?

To answer this question, the post-test mean scores and standard deviations of both groups were calculated and compared, as summarized in Table 1.

Table 1: Descriptive Statistics of Post-test Achievement Scores by Instructional Strategy

Instructional Strategy Group	Sample Size	Post-test Mean	Standard Deviation	Mean Difference
Experimental (CBT)	190	69.27	8.79	15.31
Control (Conventional)	190	53.96	10.30	

As shown in Table 1, the experimental group exposed to the Computer-Based Tutorial Instructional Strategy achieved a post-test mean score of 69.27 with a standard deviation of 8.79. The control group taught via the conventional method achieved a lower post-test mean score of 53.96 with a standard deviation of 10.30. This resulted in a descriptive post-test mean difference of 69.27 in favor of the CBTIS group, suggesting that the digital tutorial strategy led to higher academic performance.

Research Question 2

What is the difference in the post-test academic achievement mean scores between male and female Biology students exposed to the CBTIS?

To evaluate performance across gender lines within the experimental group, the scores of male and female participants were calculated separately, as displayed in Table 2.

Table 2: Descriptive Statistics of CBTIS Post-test Achievement Scores by Gender

Gender Category (CBT Group)	Sample Size	Post-test Mean	Standard Deviation	Mean Difference
Male Students	98	70.10	8.15	0.04
Female Students	92	70.06	9.05	

Table 2 shows that male students within the experimental group achieved a post-test mean score of 70.10, while female students achieved a nearly identical post-test mean score of 70.06. The resulting mean difference of 0.04 indicates that both genders achieved very similar academic outcomes when using the interactive CBTIS package.

Testing Null Hypothesis

Hypothesis One: There is no significant difference between the post-test mean academic achievement scores of students taught Biology using the Computer-Based Tutorial Instructional Strategy (CBTIS) and those taught using the conventional instructional method.

An Independent Samples t-test was conducted to determine if the mean difference shown in Table 1 was statistically significant. The results are presented in Table 3.

Table 3: Independent Samples t-test for Post-test Scores by Instructional Strategy

Strategy Group	N	Mean		df	t	sig.2tailed	Remark
Experimental (CBT)	125	69.27	8.79	245	15.55	0.000	**Significant**
Control (Conventional)	122	53.96	10.30				

The inferential data in Table 3 indicates a highly significant difference between the two instructional groups. Because t (245) = 15.55, p= 0.00, which is less than significance level of 0.05, the first null hypothesis is rejected. This indicated that the higher academic performance observed in the CBTIS group was statistically significant and directly related to the instructional intervention.

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Hypothesis Two: There is no significant difference between the post-test mean academic achievement scores of male and female students taught Biology using the CBTIS.

An Independent Samples t-test was conducted on the experimental group data to evaluate gender-based differences, as summarized in Table 4.

Table 4: Independent Samples t-Test for CBT Post-test Scores by Gender

Gender Category	N	Mean		df	t	Sig.2Tailed	Decision
Male Students	50	70.10	8.15	123	0.031	0.975	**Retained**
Female Students	75	70.06	9.05				

The statistics in Table 4 show that the difference between male and female students using CBTIS was not significant. Since t(188)= 0.031, p = 0.975, which is greater than the chosen significance value of 0.05, the second null hypothesis is retained. This demonstrates that the CBTIS worked effectively for both male and female students without favoring either gender.

Discussion of Findings

The empirical findings from this study demonstrate the pedagogical value of integrating technology into science education. Reversing the first null hypothesis showed that students exposed to the CBTIS package performed significantly better than those who learned through standard lecture methods. This finding is inline with the series of findings of (Azih et al., 2022, Jean et al. 2022, Orji et al. 2026, Fashanu &Omotayo 2026) who discovered that CBT strategies have significant effects on students' academic achievement. On the other lain, it aligns with cognitive load theory, which suggests that breaking down learning into interactive steps helps students process complex information more effectively. The step-by-step modular design of the CBT system allowed students to learn at their own pace, while its immediate feedback loops helped correct misconceptions before they could disrupt subsequent lessons. In contrast, the conventional lecture method left students in a passive role, making it harder for them to fully grasp complex microscopic and ecological processes. This outcome supports earlier research highlighting that traditional, text-heavy instructional styles struggle to engage students with abstract scientific concepts. By providing an interactive learning environment, the CBT approach helped students build a stronger, more lasting understanding of the material. The analysis of the second hypothesis showed no significant performance gap between male and female students within the CBT group. Both genders achieved nearly identical mean scores, indicating that the digital tutorial strategy functions as an equitable learning tool. This is also in line with the findings of (Azih et al., 2022, Jean et al. 2022, Orji et al. 2026, Fashanu &Omotayo 2026), who found out that gender had no significant effect on students academic achievement in Biology. This lack of gender bias contradicts older educational studies that categorized computer software as a male-dominated domain. Instead, it suggests that when interactive learning materials are designed clearly and integrated directly into the classroom, they provide equal academic benefits to all students regardless of gender. These results demonstrate that a structured CBT approach can help close historical gender gaps in science education across Katsina State.

Conclusion

This study provides quantitative evidence that the computer-Based Tutorial Instructional Strategy significantly improved academic achievement in Biology compared to conventional teaching methods. By shifting the classroom from a passive lecture format to an active, self-paced learning environment, CBT helped students better master complex biological concepts. Furthermore, the intervention proved to be gender-neutral, helping male and female students improve their academic performance equally. These results suggest that expanding the use of interactive digital learning

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tools could help address long-standing challenges in secondary school science education across Katsina State.

Recommendations

Based on these findings, the following recommendations are proposed to improve secondary science education in Katsina State:

1. Biology teachers should adopt Computer - Based Instructional Strategy in teaching Biology in secondary schools in Katsina State.
2. The Katsina State Ministry of Education, in coordination with the Nigerian Educational Research and Development Council (NERDC), should systematically integrate interactive computer-based instructional software into the official secondary school biology curriculum.
3. The State Government should prioritize equipping public schools with reliable computer laboratories, stable alternative energy sources (such as solar power arrays), and up-to-date science tutorial packages to ensure consistent access for all students.
4. Regular professional development workshops and ICT-focused seminars should be organized for secondary school science teachers. These programs should focus on training educators to design, manage, and use computer-based tutorials alongside traditional teaching methods.

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