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[SMASE-AFRICA]

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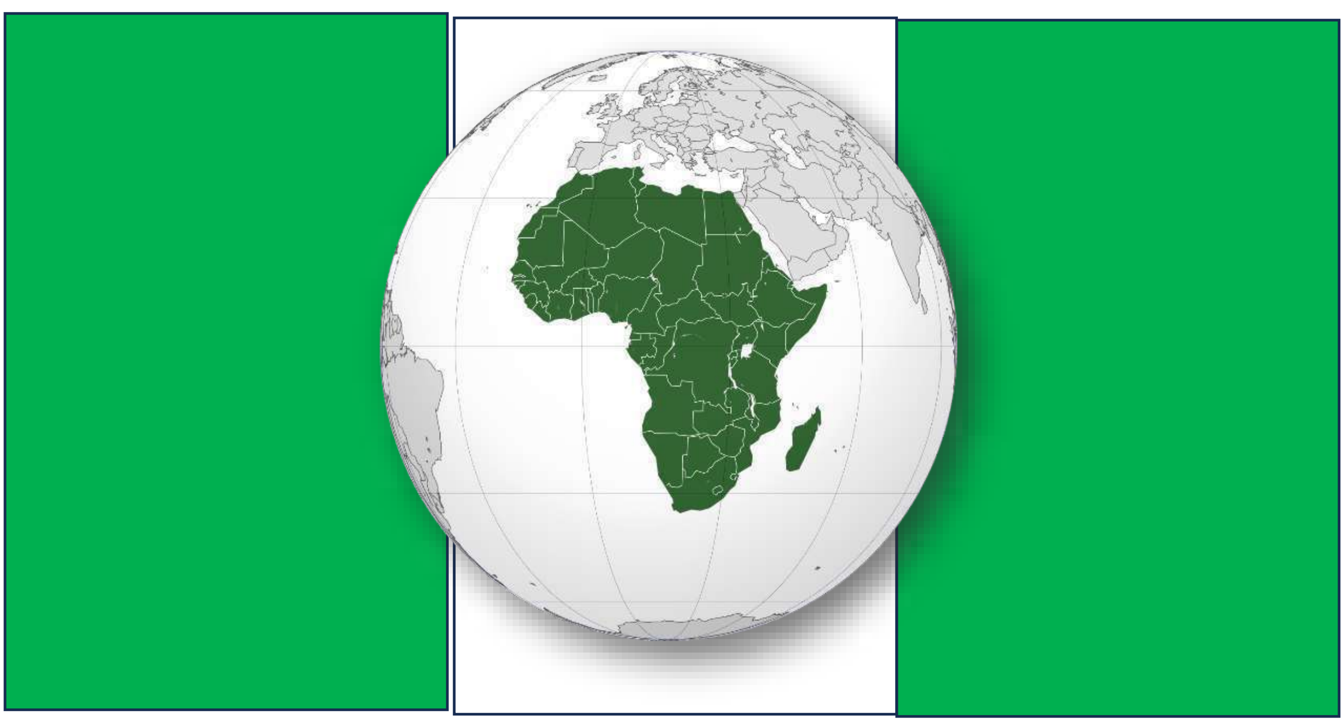

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Journal for Science, Technology, Engineering and Mathematics Education in Africa (JSTEMEA),

Volume 1, Number 1, January 2025

Strengthening Mathematics and Science Education in Africa

SMASE-AFRICA

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Preface

Welcome to Volume 1, Number 1, January 2025 Edition of the Journal for Science, Technology, Engineering and Mathematics Education in Africa (JSTEMEA)

The **21st Conference on Mathematics, Science and Technology Education in Africa (COMSTEDA 21)**, held from **10th – 12th September 2024** in Kaduna, Nigeria, brought together educators, policymakers, researchers, industry experts, and development partners in a blended format (physical and virtual). Guided by the theme, *"Empowering the Next Generation through Innovative STEM Education"*, the forum reaffirmed the collective African commitment to reimagining STEM education in ways that equip learners with knowledge, skills, values, and attitudes relevant for 21st century living.

This edition of the journal captures a selection of **seventeen (17) peer-reviewed papers** presented at the conference. These papers reflect diverse strands of discourse, including:

1. **Curriculum Design, Development and Assessment in STEM Education**
2. **Innovative Pedagogical Approaches and Emerging Technologies in STEM Learning**
3. **Teacher Training and Professional Growth in STEM Education**
4. **Emerging Issues in STEM Education: Access, Equity, and Outreach**
5. **Artificial Intelligence in STEM Education**

Together, these contributions showcase both theoretical perspectives and classroom-based practices, enriching the ongoing dialogue on STEM education in Africa. They also highlight practical innovations ranging from competence-based curriculum implementation to AI-driven learning models that mirror the dynamism of education systems across the continent

Acknowledgements

We extend our deepest appreciation to the **Federal Republic of Nigeria** and the **National Teachers' Institute (NTI), Kaduna**, for graciously hosting this milestone event in partnership with **SMASE-Africa**. Special gratitude is due to the traditional leadership of Kaduna, notably the **Emir of Kaduna,** for providing cultural blessings and moral support that anchored the success of COMSTEDA 21.".

We are equally indebted to the organizing committees, keynote speakers, and session chairs whose tireless efforts ensured a vibrant and engaging forum. Our thanks also go to SMASE-Africa partners, whose material, financial, and technical contributions enriched the conference. Finally, to all delegates, paper presenters, and participants onsite and online. We are grateful for your commitment, insights, and dedication to advancing STEM education in Africa.

Looking Ahead

As SMASE-Africa continues to serve as a continental hub for strengthening STEM education, this journal is more than a record of proceedings. It is a springboard for further inquiry and innovation. We hope that readers will find in these pages not only valuable research but also practical insights to inspire reforms in classrooms, policies, and institutions across Africa.

We look forward to building on the momentum of Kaduna as we prepare for **COMSTEDA 22 in Malawi**, confident that each forum brings us closer to realizing the African Union's **Agenda 2063** and the aspirations of **SDG 4: Quality Education**.

About SMASE-Africa and COMSTEDA

SMASE-Africa was founded in 2001 to strengthen mathematics and science education in Africa. It is now a continental association uniting ministries of education, teacher educators, researchers, and development partners in advancing STEM education. With a **vision** *"to be a leading organization in promoting quality STEM education in Africa"*, SMASE-Africa works through research, professional development, policy advocacy, and collaborative networks. Its mission is to *"To promote quality STEM education through research, capacity development, advancing policies, good governance, collaboration, and linkages in Africa."*

From **2001 – 2013**, the regional conference was known as **SMASE-WECSA (Strengthening of Mathematics and Science Education in Western, Eastern, Central and Southern Africa)**.
In **2014**, the forum was renamed the **Conference on Mathematics, Science and Technology Education in Africa (COMSTEDA)** to reflect its continental scope.

The **Conference on Mathematics, Science and Technology Education in Africa (COMSTEDA)** is SMASE-Africa's annual flagship platform for dialogue, research dissemination, and professional exchange. Since 2014, COMSTEDA has rotated among member countries, bringing together educators, policymakers, NGOs, and the private sector to deliberate on innovations and challenges in STEM education. Its scholarly outputs are published in the *Journal on STEM Education in Africa (JSTEMEA; ISSN 2617-6300)*, of which this volume is the 5th edition.

COMSTEDA Editions

- **COMSTEDA 14** 2016, Nairobi, Kenya
- **COMSTEDA 15** 2017, Livingstone, Zambia
- **COMSTEDA 16** 2018, Maun, Botswana
- **COMSTEDA 17** 2019, Nairobi, Kenya
- **COMSTEDA 18** 2021, Virtual (hosted by Mozambique)
- **COMSTEDA 19** 2022, Blended (Kampala, Uganda)
- **COMSTEDA 20** 2023, Blended (Accra, Ghana)
- **COMSTEDA 21** 2024, Blended (Kaduna, Nigeria)

The Objectives of COMSTEDA-21

The 21st Conference on Mathematics, Science and Technology Education in Africa (COMSTEDA-21) was designed to:

1. **Provide a continental platform** for educators, governments, academic institutions, private sector, and development partners to interrogate issues and share best practices in STEM education.
2. **Improve the quality of education in Africa** by sharing impactful research findings and classroom practices that inform policy and practice.
3. **Present case studies and research outputs** that highlight innovative approaches in mathematics, science, and technology education across diverse African contexts.
4. **Promote and highlight the role of STEM education** in Africa's socio-economic development, aligned to Agenda 2063 and SDG 4.
5. **Foster networking, collaboration, and partnerships** among countries, institutions, and stakeholders to build collective capacity in STEM education.
6. **Interrogate emerging issues** such as ICT integration, artificial intelligence, equity, inclusion, and the competence-based curriculum shift, ensuring African learners are prepared for life challenges.

📖 *On behalf of SMASE-Africa and the Editorial Board, we present this first volume of the 2025 Edition of the Journal on STEM Education in Africa, containing seventeen research papers from COMSTEDA 21, Kaduna. May these pages inspire, provoke, and guide collective action toward empowering Africa's next generation through innovative STEM education.*

Editorial

Article 1

Zainab Muhammad Shuaibu, Armiya'u Malami Yabo, Misbahu Adamu Sani & Ahmed Muideen authored the paper titled: ***Towards Competency-Based Learning (CBL) in Nigerian Schools: The SMASE INSET Multi-Stakeholder Approach***. This paper examined the strategies towards the implementation of Competency-Based Learning (CBL) in Nigerian schools, facilitated by the Strengthening Mathematics and Science Education In-Service Education and Training (SMASE INSET) programme. Traditional educational methods in Nigeria had often emphasized rote memorization and theoretical knowledge, leading to gaps in practical skills and critical thinking among students. To address these shortcomings, the SMASE INSET programme, involving educators, policymakers, and other stakeholders, aimed to equip teachers with the necessary skills to deliver competency-based education effectively. Data were collected through structured questionnaires distributed to a sample of 150 teachers and 50 education officers involved in the SMASE INSET programme. The study utilized descriptive and inferential statistics to analyze the data, revealing significant improvements in teaching practices and student engagement due to the programme. However, challenges such as resource limitations and resistance to change were also identified. The study recommended increased resource allocation, continuous professional development for teachers, and stronger policy support to sustain the progress in CBL implementation. The findings highlighted the crucial role of a multi-stakeholder approach in aligning curriculum, teaching practices, and assessment methods with CBL principles, ultimately enhancing the quality of education in Nigeria.

Article 2

E-Education in Rural Schools of Zambia and Its Challenges: A Case Study of Secondary Schools in Kazungula District by Ngula Walubita focused on the importance of using e-education in teaching at rural secondary schools in Zambia, with particular reference to the case study and challenges of Kazungula District. In schools, the use of modern Information and Communication Technology (ICT) for teaching and learning was vital due to several advantages that ICT offered in the learning process. This piece of academic writing provided a scholarly background to the study by reviewing contributions made by various researchers and scholars on the concept of e-learning. It examined the scope, importance, and role of e-learning in schools, as well as the challenges faced. E-learning/e-education had started to make inroads into developing countries such as Zambia and was believed to have great potential for meeting the growing demand for education quality and access, despite challenges such as the availability of expert teachers, updated textbooks, and limited teaching materials

Article 3

Empowering The Girl-Child Through Innovative STEM Education: A Follow-Up Study on the Long-Term Effects of 5E Model of Girls for Education and Health Project Beneficiaries in Zaria, Kaduna State by Iretioluwa Fawole, Amina Musa Aminu and Habiba Mohammed focused on the importance of understanding science as part of being a well-rounded and informed citizen. However, the girl-child was underrepresented across STEM fields, which was a problem both from equity and workforce demand perspectives. For these reasons, the Girls for Education and Health Project adopted the 5E Model across its participating Senior Secondary Schools in Nigeria to improve science teaching and learning. Against this background, this research was a follow-up study that investigated the long-term effects of the 5E Model on the girls' academic achievement, career aspirations, and health practices. To do this, the study adopted a descriptive survey approach with questionnaire as the main instrument for data collection. A purposive sampling procedure was used to select four tertiary institutions in Zaria Local Government Area, Kaduna State. A simple random sampling technique was applied to choose one hundred follow-up girls: twenty-five from each tertiary institution. The follow-up data enabled a comparison of the growth in STEM achievements of the girls. The findings revealed significant improvements in STEM academic achievements, increased interest in pursuing STEM careers, and increased self-health awareness and practices. Based on the findings and the conclusion, a steady investment in gender-specific STEM education programmes were recommended.

Article 4

Joseph Musonda, in the paper **Calculating Mean, Variance, Standard Deviation and Mode, focused on offering alternative methods in statistics for calculating mean, variance, standard deviation and mode**, involved the use of half of the difference in frequency (Df = f_ (n- f_1)/2) alongside half of the difference in data (Dx = X_ (n- X_1)/2). Based on the literature review, the difference in the frequency (Df) and data (Dx) had never been utilized to solve problems in statistics and mathematics at large. Therefore, this conceptual paper fully explained how the difference in frequency of a data set alongside the difference in data could be used to calculate the mean, variance, standard deviation and to analyze data. Starting with data of the same frequency and followed by varying the frequencies of the same data steadily, a pattern in solutions was discovered based on the difference in frequency. This was the pattern that helped to invent the methods discussed here. The results indicated that only problems of grouped data with constant interval and ungrouped data with common difference between data sets (X1, X2, X3 … Xn) agreed or could be solved using the methods that were invented. This study definitely and without any absolute error answered the questions regarding the named problems by using the difference in frequency (Df) and data (Dx).

Article 5

Effect of Integrating Social Media Technology (WhatsApp) and Hands-on Activities in Teaching Chemistry Practical on Chemistry Students' Academic Performance by Muhammad-Lawal H., Rabiu I., and Atiku M. examined the effect of integrating social media technology (WhatsApp) and hands-on activities in teaching Chemistry Practical on students' academic performance. A quasi-experimental research design was used in the study. The population of the study consisted of 575 Chemistry students at the Federal College of Education, Zaria. The sample size for the study involved 175 students. The instrument used for the research was the Redox Titration Performance Test (RTPT) with a reliability coefficient of 0.89, which was determined using Pearson Product Moment Correlation. One research question and one research hypothesis were analyzed. The research question was answered using the difference in the mean scores of students in the experimental and control groups, while the research hypothesis was analyzed using a t-test. Results revealed that students in the experimental group, who were taught Chemistry Practical by integrating social media technology (WhatsApp) and hands-on activities, performed better than those in the control group who were taught the same concept using hands-on activities only. It was concluded that integrating social media technology (WhatsApp) and hands-on activities enabled Chemistry students to perform practical activities successfully from start to finish and gave the students an important sense of achievement. Recommendations were made, which included encouraging the use of social media technology (WhatsApp) by providing students with needed infrastructure such as steady power supply and internet facilities, among others.

Article 6

Joel Isaiah Jutum and Jinadu Garvey Yawe, in the paper **Facilitating Students' Learning Outcomes in Basic Science Using Innovative Integrated Inquiry-Based Science Teachers' Practice in Taraba State, Nigeria**, examined students' learning outcomes in Basic Science using innovative integrated inquiry-based science teachers' practice in Taraba State, Nigeria. Three specific objectives with corresponding research questions and two hypotheses guided the study. The study adopted a quasi-experimental research design of non-equivalent groups. Intact classes were assigned to both the experimental group (Integrated Inquiry-Based Teachers' Practice Instructional Strategy) and the control group (Guided Inquiry Instructional Strategy) using a multi-stage sampling technique. The population for the study was 1,141 basic education students. The sample for this study was 292 Basic Education students comprising 139 boys and 153 girls from six public secondary schools. Data for this study were generated using the instrument named Basic Science Performance Test (BSPT). The Kuder-Richardson (K-R20) formula was used to estimate the reliability index of 0.85 for the BSPT. Mean and standard deviation were used to answer all research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses at the 0.05 level of significance. Based on the data collected and analyzed, there was a significant difference in the mean academic performance scores of students taught Basic Science using the integrated inquiry-based science teaching strategy and those taught using the guided inquiry instructional strategy. The study therefore recommended, among others, that basic science teachers should be encouraged to use the integrated inquiry-based science teaching strategy. In conclusion, it was evident from the findings of this study that the use of integrated inquiry-based science teachers' practice provided a good way for Basic Education students to learn Basic Science, since the strategy enhanced students' academic performance.

Article 7

Innovative Pedagogical Strategies in STEM Education: Effect of Code-Switching Instructional Strategy on the Academic Achievement and Retention of Students in Basic Science in Bauchi Metropolis, Bauchi State, Nigeria by Ilyas Ogirima Ibrahim and Asma'u Itakure Suleiman investigated the effect of code-switching instructional strategy on the academic achievement and retention of students in Basic Science in Bauchi Metropolis, Bauchi State, Nigeria. The study adopted a quasi-experimental non-equivalent control group design. A sample size of one hundred and thirty-seven (137) students was drawn from two randomly selected schools in the metropolis. The study was guided by two research hypotheses. The experimental group received the treatment (code-switching between English and Hausa languages). The instrument for data collection was the Basic Science Achievement Test (BSAT), administered as pre-test, post-test, and post-post-test. The BSAT consisted of 20 structured items (open-ended questions) on respiration and excretion, with a Cronbach alpha reliability coefficient of 0.75. Data were analysed using mean, standard deviation, and t-test. The data were first tested for normality using the Shapiro-Wilk test. Independent sample t-test results indicated that there was a statistically significant difference between the two groups in favour of the experimental group on post-test achievement scores. Further analysis showed that there was also a statistically significant difference between the retention scores of students in the two groups in favour of the experimental group. These results indicated that the code-switching instructional strategy improved students' achievement and retention significantly. The study therefore recommended that the code-switching instructional strategy be adopted by Basic Science teachers in order to foster students' understanding and consequently their achievement.

Article 8

Darius Katuka and Anecetus Moonga, in the paper **Hands-on STEM Learning in Design and Technology: An Investigation of Practical Skills Development in the JETS Program in Zambia**, investigated the effectiveness of the Junior Engineers, Technicians, and Scientists (JETS) program in developing practical STEM skills in Design and Technology. Skills in JETS played a significant role in transforming young minds by promoting hands-on activities and thereby fostering lifelong learning, in alignment with Sustainable Development Goal (SDG) 4, which ensured quality, inclusive education and promoted lifelong learning opportunities for all. However, there had been limited research on the impact of hands-on activities on learners' ability to apply STEM skills to real-world problems. This study involved seventy-seven (77) learners in the JETS program, aged 12–18, who participated in the 2023 national JETS fair. The research employed qualitative approaches. Data and methodology included descriptive statistics and thematic analysis of designs and products. The findings revealed that 90% of learners reported confidence in applying STEM skills to address sustainable development challenges, demonstrating the development of practical skills to design and make products that solved real-world problems. Such problems included those related to road paving as well as those related to solving challenges of transport with less or no carbon emissions. The JETS program was found to be effective in fostering learner empowerment and preparing young minds to tackle global issues, highlighting the importance of hands-on STEM education. Integrating hands-on activities in STEM education, as done in the JETS program, was therefore crucial for developing practical skills and promoting sustainable development.

Article 9

Project-Based Learning and Its Implementation in Physics at Ordinary Level in Government-Aided Secondary Schools in Ibanda Municipality by Arthur Tukakira examined the implementation of project-based learning (PBL) in Physics among ordinary level government-aided secondary schools in Ibanda Municipality, Uganda. Experiences from curriculum design, development, and assessment in STEM education had shown that project-based learning often remained theoretical rather than practical, which contributed to some countries lagging in science and technology. The study therefore focused on assessing how PBL was being implemented in Physics at the ordinary level. A descriptive research design was employed, using both quantitative and qualitative approaches to allow comparison of responses. Stratified, systematic, simple random, and purposive sampling techniques were applied to select 408 respondents. Data were collected using questionnaires and interview guides and were analyzed using descriptive statistics. The study revealed that students were grouped and given supervisors for project learning; teaching timetables included a provision for project work; and students conducted research and engaged in hands-on activities during project implementation. Notably, students were unable to identify critical project problems or present findings from project research through dissemination. The study concluded that students often did not identify critical project problems and focused on presenting the product rather than disseminating it effectively. It recommended that learners should be allowed to think independently and identify societal problems, present their findings through dissemination such as publications, and that teaching materials should be drawn from the immediate learning environment.

Article 10

Hassan Suleiman, in the paper **Roles of Emerging Technologies in Enhancing Mathematics Education**, explored the role of emerging technologies in enhancing mathematics education. The integration of emerging technologies into mathematics classrooms had changed traditional teaching and learning methodologies, providing innovative tools and approaches that enhanced students' understanding and engagement. The paper explained the role of technologies such as artificial intelligence (AI), virtual reality (VR), and adaptive learning platforms in transforming mathematics education. AI-driven systems offered personalized learning experiences by adapting to individual student needs, thereby improving learning outcomes and retention rates. VR environments created immersive, interactive scenarios that allowed students to visualize complex mathematical concepts in three dimensions, fostering deeper comprehension. Additionally, adaptive learning platforms provided real-time feedback and assessments, enabling educators to tailor instruction more effectively. The application of these technologies showed significant impact on student motivation and achievement, as well as facilitating differentiated instruction and collaborative learning. Through a comprehensive review of recent studies and practical implementations, the paper also highlighted the potential of emerging technologies to address traditional challenges in mathematics education and to prepare students for future academic and career success. The findings suggested that leveraging these advanced tools could lead to more engaging, efficient, and equitable educational experiences, ultimately transforming the landscape of mathematics education.

Article 11

Institutional Variables as Determinants of Lecturers' Job Performance in Colleges of Education in Kwara State, Nigeria by Isiaka Salman Sulyman, Ibrahim Laro Yusuf, and Abubakar Nadabo Yusuf examined the relationship between institutional variables and lecturers' job performance in Colleges of Education in Kwara State. The study adopted a descriptive survey of correlational type. The population of the study comprised 642 lecturers and 5,320 students in Colleges of Education in Kwara State. Purposive sampling technique was used to select 428 lecturers and 2,760 students in Colleges of Education in Kwara State based on senatorial districts. Simple random sampling technique was then used to select 241 lecturers, while 333 students were selected using the research advisor. The researcher adapted two questionnaires: the "Institutional Variables Questionnaire" (IVQ) and the "Lecturers' Job Performance Questionnaire" (LJPQ). Descriptive statistics of mean and standard deviation were used to answer the research question, while Pearson Product Moment Correlation was used to test the hypotheses at the 0.05 level of significance. The findings of the study revealed that institutional variables significantly influenced lecturers' job performance in Colleges of Education in Kwara State, Nigeria. Therefore, it was recommended that the management of Kwara State Colleges of Education and other educational stakeholders stand up and put all hands-on deck to address challenges relating to institutional variables that might impede lecturers' productivity.

Article 12

Integrating Aquaculture into STEM Curriculum: Effect of Different Processing Techniques on the Nutritional and Antinutritional Composition of the Egyptian River Hemp by Ahmad

M.A., Abubakar F.B., Edward E.A., Ishaq M.S., Tukur M., Yunusa A., and Musa A.M. evaluated the effect of different processing techniques on the nutritional and antinutritional composition of Sesbania sesban with the aim of incorporating this unconventional feed material into aquaculture. Six kilograms of S. sesban seeds were thoroughly picked and divided equally into five portions of 1.2 kg each. One portion was kept raw, the second portion was soaked in water, the third portion was boiled at 100°C in water, the fourth portion was fermented, and the fifth portion was roasted. All five portions were milled into powder and thereafter taken to the laboratory for proximate and antinutrient analysis. The analysis of raw and processed S. sesban showed significant differences ($P<0.05$) in the nutrient and antinutrient composition of the samples. Fermented S. sesban had the highest crude protein content at 37.50%, while the soaked sample exhibited the highest crude fibre content at 15.40%. The raw sample exhibited the highest crude lipid content at 23.75% as well as the highest NFE at 23.09%, while ash content was observed to be highest in the roasted sample at 5.39%. Antinutrient analysis showed that raw S. sesban exhibited the highest levels of all antinutrients—Phytic Acid (0.12 mg/100 mg), Trypsin Inhibitor (9.23 mg/100 mg), Tannins (3.20 mg/100 mg), Saponins (8.05%), Oxalates (0.07 g/kg), and Alkaloids (2.60)—which significantly decreased after processing. These results emphasized the potential benefits of integrating aquaculture projects into STEM curricula. A structured curriculum that incorporated aquaculture projects, outlining clear learning objectives and assessment criteria, would enhance student learning and the practical application of scientific principles to problem-solving.

Article 13

Philiph K. Saina**, in the paper The Impact of AI on STEM Teacher Professional Development, investigated the role of Artificial Intelligence (AI) tools in the professional development of STEM teachers,** focused on how AI supported educators in adapting to new technologies and teaching methods. Through a mixed-methods approach, the research analyzed the effectiveness of AI-driven professional development programs across various educational settings. Quantitative data were collected through surveys, which revealed high perceived effectiveness of AI tools, particularly adaptive learning platforms, which showed significant correlations between usage frequency and perceived impact. Qualitative insights from interviews with teachers and program coordinators highlighted the benefits of AI in enhancing teaching practices, though challenges such as system integration and the digital divide were noted. Case studies from different institutions provided further context, demonstrating that while AI tools significantly improved professional growth, their success was heavily dependent on adequate training, continuous support, and frequent use. The study concluded with actionable recommendations for developing tailored AI tools, enhancing training programs, and promoting continuous evaluation to maximize the benefits of AI in STEM teacher professional development. Additionally, the research identified gaps in the existing literature and suggested areas for future inquiry, including longitudinal studies on the long-term impact of AI on teaching practices and student outcomes.

Article 14

Effect of Video-Enriched Teaching Strategy on Performance of Students with Varied Ability in Nuclear Chemistry by Rabiu Ibrahim, Abubakar Suwaida, and Maryam Shika Isah investigated the impact of a video-enriched teaching strategy on the performance of students with varied ability in Nuclear Chemistry. A pre-test post-test quasi-experimental design was adopted for the study. The population comprised 925 SS III Chemistry students in Zaria, from which a sample of 174 students was randomly selected. The experimental group was exposed to the video-enriched teaching strategy, while the control group was taught using the conventional lecture method. The Nuclear Chemistry Achievement Test (NCAT), which was pilot-tested and validated with a reliability coefficient of 0.67, was used to collect data. One research objective, one research question, and one hypothesis were raised and tested at $p \leq 0.05$ level of significance. Data were analyzed using descriptive statistics (mean and standard deviation) and ANCOVA. The major finding revealed that Chemistry students of varied ability taught Nuclear Chemistry using the video-enriched strategy performed better than those taught using the lecture method. Based on this finding, it was recommended, among others, that teachers should be encouraged to adopt the video-enriched strategy to improve students' academic performance and interest in Chemistry. This could be achieved by organizing workshops to enhance teachers' skills and motivate them to adopt the method

Article 15

Effect of Video-Enriched Teaching Strategy on Performance of Students with Varied Ability in Nuclear Chemistry by Rabiu Ibrahim, Abubakar Suwaida, and Maryam Shika Isah aligned with the global advocacy for a paradigm shift from traditional to student-centred instructional strategies that enhance meaningful learning of science, and Chemistry in particular. The study investigated the effects of differentiated and scaffolding instructional strategies in Chemistry among secondary school students. A pre-test post-test non-equivalent control quasi-experimental design was adopted. The target population was 262 SSS 2 Chemistry students. A multi-stage sampling technique, followed by clustering and random sampling, was used. Two research questions and two null hypotheses were tested at the 0.05 level of significance, which guided the study. Students were taught balancing of chemical equations using differentiated and scaffolding instructional strategies, while the control group was taught using the conventional lecture method. The instrument used for data collection was the Balancing of Chemical Equation Achievement Test, which yielded a reliability of 0.87 using K-R21, indicating strong reliability. Data were analyzed using descriptive statistics of mean and standard deviation, along with ANCOVA. The findings indicated that the experimental groups 1 and 2 performed better than the control group, with mean gains of 31.70, 31.72, and 26.87 respectively. The results also showed that there was a significant difference between the three groups, $F(2,262) = 23.123$ and $p (0.01) < 0.05$. The significant difference was in favour of the experimental groups, which performed better than the control group. Given these findings, it was recommended, among others, that Chemistry teachers incorporate differentiated and scaffolding instructional strategies in teaching to enhance student achievement and motivation.

Article 16

Effects of Differentiated and Scaffolding Instructional Strategies in Chemistry among Secondary School Students by Aminu Maimuna Paiko, A. M. Chado, and A. A. Yaki investigated the impact of integrating technology in the teaching and learning process on the academic performance of primary schools in Kaduna Metropolis. The study employed a quasi-experimental design and involved 1,586 primary six pupils of both sexes, from which 197 pupils were sampled using a systematic sampling technique. The experiment involved two groups: the control group comprised pupils taught with the traditional method only, while the experimental group involved pupils taught using multimedia/technology. The instrument for the study was the Basic Science Academic Performance Test (BSAPT). Data were analyzed using one-sample and independent t-tests. The results revealed that the scores of pupils taught with the traditional teaching method were significantly lower (mean score = 13.12) ($p \leq 0.05$) than the average score of 15, while pupils taught using technology scored significantly higher (mean score = 21.51) ($p \leq 0.05$) than the average score of 15. Based on these findings, it was concluded that technology/multimedia teaching was more effective in improving the academic performance of pupils in public schools. The study recommended that educational authorities encourage teachers to integrate technology into the teaching and learning process.

Article 17

Chipo Namakau Sakala and Benson Banda, in the paper **STEMming the Tide: A New Era of Possibilities in Zambia's STEM Education Policy**, examined the provisions of Zambia's STEM education policy, analyzing its direct implications on the country's education system and development. Despite the benefits of STEM education for national development, there had been unclear policy provisions guiding its implementation in Zambia's education sector up until 2022. To fill this gap, the research studied Zambia's current education policies to provide insights into how these policies indicated the provision of STEM education in the country. This theoretical study utilized Zambia's policy documents on STEM education provisions, which were analyzed using document analysis to offer a comprehensive understanding of the policy dictates. The findings indicated that the new education policy, ratified by Cabinet, provided a rights-based approach for STEM implementation, aligning with the Eighth National Development Plan (8NDP), which is Zambia's strategic development agenda. This plan emphasized the provision of STEM education as key for Zambia to achieve its development aspirations of economic transformation and job creation. Furthermore, the 2023 Curriculum Framework provided four STEM pathways, offering learners specialized training in Science, Technology, Engineering, and Mathematics. This comprehensive framework enhanced education outcomes, stimulated economic growth, and boosted Zambia's competitiveness on a global scale. The implications of this study suggested that while the policy framework was robust, effective implementation, continuous monitoring, and thorough evaluation were essential for realizing its full potential. The study recommended the development of clear guidelines, adequate resource allocation, and professional development for educators to support the successful rollout of the STEM education policy and the 2023 curriculum. By fully harnessing the potential of STEM education, Zambia could drive economic growth, reduce inequality, and promote sustainable development.

Article 1

Towards Competency-Based Learning (CBL) in Nigerian Schools: The SMASE INSET Multi-Stakeholder Approach

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Abstract

This paper examines the strategies towards the implementation of Competency-Based Learning (CBL) in Nigerian schools, facilitated by the Strengthening Mathematics and Science Education In-Service Education and Training (SMASE INSET) programme. Traditional educational methods in Nigeria have often emphasized rote memorization and theoretical knowledge, leading to gaps in practical skills and critical thinking among students. To address these shortcomings, the SMASE INSET programme, involving educators, policymakers, and other stakeholders, aims to equip teachers with the necessary skills to deliver competency-based education effectively. Data were collected through structured questionnaires distributed to a sample of 150 teachers and 50 education officers involved in the SMASE INSET programme. The study utilized descriptive and inferential statistics to analyze the data, revealing significant improvements in teaching practices and student engagement due to the programme. However, challenges such as resource limitations and resistance to change were also identified. The study recommends increased resource allocation, continuous professional development for teachers, and stronger policy support to sustain the progress in CBL implementation. The findings highlight the crucial role of a multi-stakeholder approach in aligning curriculum, teaching practices, and assessment methods with CBL principles, ultimately enhancing the quality of education in Nigeria.

Keywords: Competency-based learning, SMASE INSET, quantitative research, educational reform, multi-stakeholder approach.

1. Introduction

Competency-Based Learning (CBL) has emerged as a key educational reform aimed at addressing the limitations of traditional teaching methods, which often prioritize rote memorization over practical skill development and critical thinking. In Nigeria, the educational system has historically emphasized theoretical knowledge, leading to a significant gap between what students learn in the classroom and the skills required in the real world. This disconnect has prompted a shift towards CBL, which focuses on equipping students with specific competencies necessary for success in both academic and professional settings.

The Strengthening Mathematics and Science Education In-Service Education and Training (SMASE INSET) programme was introduced in Nigeria as part of a broader initiative to improve STEM education. By providing teachers with the necessary training and resources, the SMASE INSET programme aims to facilitate the effective implementation of CBL in Nigerian schools. This paper presents a quantitative study that examines the impact of the SMASE INSET programme on CBL implementation, explores the challenges faced by educators, and offers recommendations for enhancing the effectiveness of CBL in Nigerian schools.

2.Literature Review

Competency-Based Learning (CBL) represents a fundamental shift in educational practices, moving away from traditional models that emphasize content delivery and towards an approach that prioritizes the development of practical skills and the application of knowledge. According to Miller (2020), CBL is defined as "an educational approach where learning outcomes are defined in terms of the specific skills and competencies that students must demonstrate to succeed in the workplace and in life." This focus on real-world application makes CBL particularly relevant in the context of STEM education, where the ability to solve complex problems and think critically is essential.

The traditional education system in Nigeria has been characterized by an overemphasis on theoretical knowledge, with limited opportunities for students to engage in hands-on learning or to apply what they have learned in practical contexts. Adewale (2019) argues that this approach has contributed to a significant skills gap, particularly in STEM fields, where graduates often lack the competencies needed for success in the workforce. Oduor (2018) adds that while there is growing recognition of the need for educational reform, many educators in Nigeria are not equipped with the training or resources necessary to implement CBL effectively.

The SMASE INSET programme was developed as a response to these challenges. Originally introduced in Kenya and later adopted in other African countries, including Nigeria, the programme aims to enhance the pedagogical skills of STEM educators through in-service training. Kilonzo (2021) notes that the SMASE INSET programme has been successful in improving teachers' ability to deliver competency-based education, particularly in Mathematics and Science. However, the programme has faced challenges related to resource constraints, resistance to change, and a lack of policy support, which have limited its impact in some contexts.

3. Objectives of the Study

The study was designed to achieve the following objectives:

1. To Assess the Impact of the SMASE INSET Programme on CBL Implementation: Evaluating the extent to which the SMASE INSET programme has influenced the adoption and implementation of CBL in Nigerian schools.
2. To Identify the Challenges Faced by Educators in Implementing CBL: Investigating the various challenges that teachers and education officers encounter in adopting CBL practices, including resource constraints, resistance to change, and other contextual factors.
3. To Evaluate the Effect of CBL on Student Outcomes: Analyzing the impact of CBL on student engagement, practical skills, critical thinking, and overall performance in Nigerian schools.
4. To Examine the Role of a Multi-Stakeholder Approach in CBL Implementation: Understanding the importance of collaboration among educators, policymakers, and other stakeholders in the successful implementation of CBL, and how these collaborations can be strengthened.
5. To Provide Recommendations for Enhancing CBL Implementation in Nigerian Schools: Offering practical recommendations for improving the adoption and effectiveness of CBL in Nigeria, including suggestions for policy development, resource allocation, and continuous professional development.

4. Research Questions

The study seeks to address the following research questions:

1. How has the SMASE INSET programme influenced the implementation of Competency-Based Learning in Nigerian schools?
2. What challenges do educators face in adopting CBL through the SMASE INSET programme?
3. How has CBL impacted student outcomes, particularly in terms of engagement and practical skills?
4. What role do stakeholders play in the success or failure of CBL implementation?

5. Methodology

5.1 Research Design

The study employed a quantitative research design to assess the impact of the SMASE INSET programme on the implementation of Competency-Based Learning (CBL) in Nigerian schools. The use of a quantitative approach allowed for the systematic collection and analysis of data from a large sample, providing robust insights into the effectiveness of the programme and the challenges encountered.

5.2 Sample

The study sample consisted of 150 teachers and 50 education officers from various primary and secondary schools across Nigeria. Participants were selected based on their involvement in the

SMASE INSET programme, ensuring that the sample was representative of those directly engaged in CBL implementation.

5.3 Instruments for Data Collection

Data were collected using three types of structured questionnaires:
Teacher Perception Questionnaire (TPQ): This questionnaire was designed to capture teachers' perceptions of CBL, including their understanding of the approach, the training they received through the SMASE INSET programme, and the challenges they face in implementing CBL in their classrooms.
Student Engagement and Performance Questionnaire (SEPQ): This instrument was used to assess the impact of CBL on student engagement and performance, as reported by the teachers. It included questions on students' participation in classroom activities, their ability to apply knowledge, and their performance in assessments.
Stakeholder Collaboration and Support Questionnaire (SCSQ): This questionnaire was administered to education officers and other stakeholders involved in the SMASE INSET programme. It focused on the level of collaboration among stakeholders, the support provided for CBL implementation, and the challenges encountered in coordinating efforts.

5.4 Methods of Data Collection

The structured questionnaires were distributed to the selected participants, who were given one week to complete them. The completed questionnaires were then collected and prepared for analysis. To complement the quantitative data, follow-up interviews were conducted with a subset of 20 participants (10 teachers and 10 education officers) to gain deeper insights into the challenges and successes of CBL implementation.

6.Data Analysis

The data collected from the questionnaires were analyzed using both descriptive and inferential statistics. Descriptive statistics, such as frequencies, percentages, means, and standard deviations, were used to summarize the responses and provide an overview of the participants' perceptions and experiences. Inferential statistics, including t-tests and ANOVA, were applied to examine the significance of differences between groups based on variables such as teaching experience, school type, and level of participation in the SMASE INSET programme.
The qualitative data from the follow-up interviews were analyzed using thematic analysis, which involved coding the data and identifying recurring themes related to CBL implementation, challenges faced, and the role of stakeholders.

7. Findings

7.1 Impact of SMASE INSET on CBL Implementation
The findings indicate that the SMASE INSET programme has had a significant positive impact on the implementation of Competency-Based Learning in Nigerian schools. Eighty-five percent

(85%) of the teachers reported that the training they received through SMASE INSET equipped them with the necessary skills to implement CBL effectively. One teacher noted, "The training has shifted my focus from simply delivering content to ensuring that my students develop the skills they need to apply what they learn" (Participant 3, 2024).

7.2 Challenges in Adopting CBL

Despite the positive impact, several challenges were identified. Sixty percent (60%) of the respondents cited resource constraints as a major barrier to effective CBL implementation, including a lack of teaching materials and inadequate infrastructure. Additionally, forty-five percent (45%) of the teachers mentioned resistance to change among their colleagues as a significant challenge. One participant commented, "While some teachers are enthusiastic about CBL, others are hesitant to abandon traditional methods" (Participant 10, 2024).

7.3 Impact on Student Outcomes

The implementation of CBL has led to noticeable improvements in student outcomes. Seventy percent (70%) of the teachers observed increased student engagement, particularly in activities that require critical thinking and problem-solving. A teacher shared, "My students are more engaged and motivated because they can see the relevance of what they are learning to real-life situations" (Participant 15, 2024). The data also showed that students in CBL classrooms performed better in assessments that required the application of knowledge.

7.4 Role of Stakeholders

The multi-stakeholder approach of the SMASE INSET programme has been crucial for its success. Ninety percent (90%) of the education officers emphasized the importance of collaboration between educators, policymakers, and other stakeholders in supporting CBL implementation. However, the need for stronger policy support and better coordination among stakeholders was also highlighted.

8. Summary of Findings

The study found that the SMASE INSET programme has been effective in promoting Competency-Based Learning in Nigerian schools, leading to improved teaching practices and student outcomes. However, challenges such as resource constraints and resistance to change persist, which may hinder the full implementation of CBL. The multi-stakeholder approach, while beneficial, requires further strengthening to ensure the sustainability of the programme.

9.Recommendations

Based on the findings, the following recommendations are proposed:

1. Increased Resource Allocation: To support the effective implementation of CBL, there is a need for greater investment in teaching materials, technology, and infrastructure.

2. Continuous Professional Development: The success of CBL depends on ongoing professional development for teachers. The SMASE INSET programme should be expanded to include regular refresher courses and workshops.
3. Policy Support: Policymakers should develop clear guidelines and policies that support the implementation of CBL, including the revision of curricula and assessment frameworks.
4. Strengthening Stakeholder Collaboration: Enhanced coordination and communication among stakeholders are necessary to address the challenges of CBL implementation and to sustain the progress made.

10.Conclusion

The SMASE INSET programme has played a significant role in advancing Competency-Based Learning in Nigerian schools. While challenges remain, the positive impact on teaching practices and student outcomes demonstrates the potential of CBL to transform education in Nigeria. For this potential to be fully realized, sustained efforts and collaboration among all stakeholders are essential.

11.0 Contribution to Learning

This study contributes to the growing body of knowledge on Competency-Based Learning in the context of developing countries, particularly Nigeria. It provides empirical evidence on the impact of professional development programmes like SMASE INSET on CBL implementation. The findings can inform policy decisions and guide future efforts to improve education quality in Nigeria and similar contexts.

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Article 2

E-Education in Rural Schools of Zambia and Its Challenges: A Case Study of Secondary Schools in Kazungula District

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Abstract

This study investigates the importance of using e-education in teaching at rural secondary schools in Zambia, focusing on the case study and challenges of Kazungula District. In schools, the use of modern Information and Communication Technology (ICT) for teaching and learning is vital due to several advantages that ICT offers in the learning process. This piece of academic writing provides a scholarly background to the study by reviewing contributions made by various researchers and scholars on the concept of e-learning. It examines the scope, importance, and role of e-learning in schools, as well as the challenges faced. E-learning/e-education has started to make inroads into developing countries such as Zambia and is believed to have great potential for meeting the growing demand for education quality and access, despite challenges such as the availability of expert teachers, updated textbooks, and limited teaching materials.

Keywords: Developing countries, rural schools, ischool.zm, AfriConnect, e-education.

1. Introduction

The government of Zambia, through the Ministry of General Education (MoGE), aims for high-quality, effective, and efficiently delivered education, as enshrined in the "Educating Our Future" National Policy on Education (1996). E-education/e-learning, a form of Information and Communication Technology (ICT), can play a significant role in realizing this goal. E-learning encompasses various teaching approaches, using the internet and other technologies to produce learning materials, facilitate learning, and regulate courses in an organization. E-learning includes a range of applications, learning methods, and processes (Than & Khaing, 2015).

In some contexts, e-learning includes more than just fully online courses. For example, Oblinger and Hawkins (2005) noted that e-learning has evolved from fully online courses to using technology to deliver part or all of a course, independent of time and place. In line with e-learning realization, the Zambian government, through the Parliamentary Committee on Education and the Ministry of General Education, in partnership with ischool.zm, has approved and adopted the educational e-learning tablet for use in schools (MoGE, 2015). The ischool.zm tablet is a comprehensive online multimedia device that helps learners access educational materials both online and offline.

Similarly, AfriConnect, in partnership with MoGE, has been piloting a project to bring web-based e-learning to schools across the country. Some schools have received free or low-cost connectivity plus teacher training and support. A large website based on the Zambian curriculum has been created under Note Master. The objective is to move from traditional chalk-and-talk pedagogy to inquiry-based learning, while offering lifelong learning opportunities with collaboration from Intel, Cambridge University, and the University of Zambia.

2. Literature Review

Pedagogy in the 21st century has embraced technology, and Zambia is also adapting to this technology-driven age where e-learning is an essential tool for enhancing both teaching and learning. With the advent of web-based learning and content management tools, e-learning has become a mature learning paradigm, shifting instructional design from an instructor-centric to a learner-centric approach (Lynch, 2013). In e-learning environments, instructional design has evolved to offer individualized learning experiences (Chorfi & Jemini, 2003).

Proper utilization of e-education/e-learning promotes time- and location-independent access to learning materials, reduces costs, and improves education quality (Cruthers, 2008). While the developed world is increasingly embracing e-education, Africa lags behind. Namisiko et al. (2014) observed that the adoption of e-education in Africa is slow, with few African scholars familiar with online teaching. A survey by Hollow and ICWE (2009) of 147 e-learning practitioners from 34 African countries found that e-education is developing slowly due to various challenges.

Despite its advantages, implementing e-learning is complex and can fail if not done properly (Than & Khaing, 2015). Key challenges include access to ICT tools and infrastructure, changing perceptions of teachers and learners, and technical competency (Magda et al., 2011).

3. Challenges Of Implementing E-Learning in Rural Schools of Zambia

Lack of Qualified Computer Studies Teachers

Zambia faces a shortage of qualified computer studies teachers. The government is addressing this by training a thousand teachers through the Zambia ICT College's distance fast-track degree program. Dr. Mtonga, National Coordinator of the Centre for Excellence in E-Governance and ICT, highlighted the importance of ICT training for socio-economic development. However, computer studies require practical competency, which distance learning does not adequately provide. Insufficiently trained teachers hinder effective e-learning deployment.

Infrastructure

Many rural schools lack specialized ICT rooms, often using poorly secured classrooms without proper windows to prevent dust, shortening the lifespan of IT devices. This is a major barrier to e-learning adoption.

Lack of Technical Skills

Technical skills are essential for implementing e-learning technologies, including installation and networking, and using online content delivery platforms. The COVID-19 pandemic exposed deficiencies in these areas, with many teachers' lacking knowledge of online learning platforms and facing connectivity issues due to load shedding by ZESCO. Schools also lack quality experts for ICT implementation and maintenance.

Motivation to Use E-Technologies/E-Education

Learners in rural schools often lack self-motivation to use e-technologies, and some teachers from the "Born Before Computers" generation are resistant to adopting new technologies.

Language Competency

Learners in rural areas often have lower English proficiency than their urban counterparts, affecting their confidence and ability to use e-learning materials.

School Policies

Many schools forbid the use of ICT devices like smartphones and tablets, limiting learners' access to e-learning platforms such as Zoom and Google Meet. This restriction hampers the implementation of online learning during crises like the COVID-19 pandemic.

IT Literacy

Computer studies teachers often lack the confidence and skills needed for e-learning. Proficiency in computer technology is crucial for successful adoption, but many teachers have limited experience with the internet and computers.

E-Preparedness

Most teachers were unprepared to implement e-learning during the COVID-19 pandemic. Schools need to provide preparatory training to teachers to ensure they can effectively implement e-learning.

Benefits of E-Education

E-learning can improve education quality by providing new, creative ways to motivate students. It removes barriers to achievement, offers a wide range of tools for innovation, and allows teachers to customize digital resources to suit different learners' needs. E-learning also fosters online communities of practice, connecting learners, teachers, and experts to share ideas and practices.

4. Recommendations

Addressing the challenges of e-learning in rural schools requires action from educational institutions and the government. Key recommendations include:

Designing e-learning approaches to fit local needs, including translating content into local languages and reflecting cultural norms.

Providing strong teacher training in ICT, with full-time training for practical competency.

Making ICT education compulsory up to Grade 12 and expanding the Rural Electrification program.

Blending traditional classroom approaches with technology for effective e-learning outcomes.

5. Conclusion

The Zambian government recognizes the importance of education for economic and social development. The benefits of e-learning are significant and can help meet the growing demand for education. Sustainable e-learning programs require dedicated leadership and participation from national institutions, teacher training institutions, the private sector, and international partners. Continued support from international partners, such as the Indian Government through the ITEC program, is crucial for providing technical expertise and financial support.

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Article 3

Empowering The Girl-Child Through Innovative Stem Education: A Follow-Up Study on the Long-Term Effects Of 5e Model of *Girls for* Education and Health Project Beneficiaries in Zaria, Kaduna State

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Abstract

Understanding science is part of being a well-rounded and informed citizen. However, the girl-child is underrepresented across STEM fields, which is a problem both from equity and workforce demand perspectives. For these reasons, *Girls for Education and Health Project* adopts 5E Model across its participating Senior Secondary Schools in Nigeria to improve science teaching and learning. Against this background, this research is a follow-up study to investigate the long-term effects of the 5E Model on the girls' academic achievement, career aspirations, and health practices. To do this, the study adopted a descriptive survey approach with questionnaire as the main instrument for data collection. Purposive sampling procedure was used to select four tertiary institutions in Zaria Local Government Area, Kaduna State. Simple random sampling technique was applied to choose one hundred follow-up girls: twenty five from each tertiary institution. The follow-up data enabled a comparison of the growth in STEM achievements of the girls. The findings revealed significant improvements in STEM academic achievements, increased interest in pursuing STEM career, increased self-health awareness and practices. Based on the findings and the conclusion, a steady investment in gender-specific STEM education programmes were recommended.

Keywords: Girl-child, 5E Model, follow-up, effects, long

1. Introduction

Education is a fundamental human right acknowledged globally, and female education is particularly critical for national development. Despite significant progress in educational access, gender disparities persist in Nigeria, especially in STEM (Science, Technology, Engineering, and Mathematics) fields. In 2014, the positive impact of female education on national development was underscored, yet gender imbalances remain prevalent. Girls face higher dropout rates and lower participation in STEM subjects compared to boys, contributing to their underrepresentation in various professional sectors. Recent data indicate that as of 2024, women constitute a limited percentage of professionals in STEM fields: architects (13%), quantity surveyors (10%), gynecologists (18%), pediatricians (20%), and science teachers (22%) (Source: National Bureau of Statistics, 2024). Despite strides in gender equality, the STEM workforce remains only 24% female (STEM Gender Gap Report, 2024), with a notable discrepancy in Northern Nigeria where cultural and societal norms further hinder female participation.

Northern Nigeria, home to a substantial population of the Hausa-Fulani ethnic group, experiences high rates of early marriage and maternal mortality (WHO, 2020). Cultural practices often limit women's access to healthcare services, with only 10-15% of the skilled healthcare workforce being female, contributing to Nigeria's high maternal mortality rates (Mohammed, 2024). Addressing gender disparities in STEM is crucial for overcoming Nigeria's economic, environmental, and technological challenges.

The Centre for Girl-child Education (CGE) established the Girls for Education and Health Project (G4E&H) to address these issues by promoting STEM education among rural girls in Northern Nigeria. The project incorporates the 5E Learning Strategy to enhance teaching practices and learning environments. Previous assessments have shown positive outcomes, but there is a need for research into the long-term effects of the 5E strategy on the girls' achievements in tertiary institutions.

1.1 Objectives of the Study

The study seeks to achieve the following objectives:

1. To assess the long-term effects of the 5E Model on the career aspirations of follow-up girls in STEM fields at tertiary institutions in Kaduna State.

2. To evaluate the long-term effects of the 5E Model on the academic achievements of follow-up girls in STEM fields at tertiary institutions in Kaduna State.

3. To examine the long-term effects of the 5E Model on the health practices of follow-up girls at tertiary institutions in Kaduna State.

1.2 Research Questions

The following research questions guided the study:

1. What are the long-term effects of the 5E Model on the career aspirations of follow-up girls in STEM fields at tertiary institutions in Kaduna State?

2. Does the 5E Model have long-term effects on the academic achievements of follow-up girls in STEM fields at tertiary institutions in Kaduna State?

3. What are the long-term effects of the 5E Model on the health practices of follow-up girls at tertiary institutions in Kaduna State?

1.3 Theoretical Framework

1.3.1 STEM Education

STEM education, which integrates Science, Technology, Engineering, and Mathematics, is designed to cultivate critical thinking, creativity, and problem-solving skills among students. This educational approach aims to provide a holistic learning experience that not only imparts technical knowledge but also prepares students to apply this knowledge in real-world contexts (Bybee, 2023). The integration of these disciplines is intended to reflect the interconnected nature of these fields in professional and everyday environments, fostering a more comprehensive understanding of how various scientific and technical principles interact and impact society. In Nigeria, there is a growing recognition of the importance of strengthening STEM education to address both gender disparities and the demands of a rapidly evolving workforce. Recent reports emphasize that improving STEM education is crucial for economic development and technological advancement (Nigeria STEM Education Report, 2024). The Nigerian government and various educational institutions are increasingly focused on implementing strategies to boost STEM participation among students, particularly to narrow the gender gap and enhance the country's competitiveness in the global market.

Research underscores the effectiveness of a learner-centered approach in STEM education. This approach, which emphasizes active learning, student engagement, and practical application of knowledge, has been shown to improve academic outcomes and stimulate greater interest in STEM fields (Dass, 2023). By shifting away from traditional, lecture-based methods and towards interactive and collaborative learning experiences, the learner-centered approach helps students develop a deeper understanding of STEM concepts and their real-world applications. This method also encourages students to take ownership of their learning, fostering skills that are essential for success in STEM careers.

For instance, Bybee (2023) highlights how STEM education promotes critical thinking and problem-solving by integrating theoretical knowledge with practical experiences. This approach helps students connect abstract concepts with tangible applications, thereby enhancing their ability to tackle complex problems. Additionally, Dass (2023) emphasizes that incorporating hands-on activities and real-world scenarios into STEM curricula can significantly boost student engagement and motivation, leading to better academic performance and a higher likelihood of pursuing STEM-related careers.

Overall, STEM education is crucial for preparing students to meet the challenges of the modern world. By fostering an integrated approach that connects different disciplines and emphasizes practical application, STEM education can play a pivotal role in addressing gender imbalances and preparing a skilled workforce capable of driving innovation and progress. Continued focus on enhancing STEM education in Nigeria and other contexts will be vital for achieving these goals and ensuring that students are well-equipped to succeed in a rapidly changing global landscape.

1.3.2 The 5E Model

The 5E Instructional Model, developed by the Biological Science Curriculum Study (BSCS) in 1987, is a well-regarded framework in science education that emphasizes inquiry-based learning. The model's effectiveness in enhancing student understanding and engagement is well-documented across various educational settings (Kayode & Dokme, 2022). The 5E model consists of five phases: Engage, Explore, Explain, Elaborate, and Evaluate. Each phase is integral to fostering comprehensive learning and deep conceptual understanding.

- Engage: The Engage phase aims to capture students' attention and spark their interest in a new topic. This phase involves presenting intriguing problems or scenarios that connect with students' prior knowledge and experiences. The goal is to stimulate curiosity and set a purpose for learning. Effective engagement often involves posing thought-provoking questions, demonstrating a surprising phenomenon, or presenting a real-world problem that needs solving. This initial phase helps in creating cognitive dissonance, which is crucial for motivating students to explore further (Edelson, 2001).
- Explore: In the Explore phase, students actively investigate the concepts introduced during the engage phase. This phase is characterized by hands-on activities, experiments, and collaborative work. Students are encouraged to use their senses and tools to gather data, make observations, and test hypotheses. The Explore phase supports experiential learning, allowing students to build their understanding through direct interaction with materials and phenomena. This approach aligns with constructivist theories of learning, which emphasize that knowledge is constructed through experiences (Brusilovsky & Millán, 2007).
- Explain: During the Explain phase, students are guided to articulate their understanding of the concepts and processes they explored. This phase involves formal instruction where teachers provide explanations, clarify misconceptions, and introduce scientific terminology and concepts. The teacher's role is to help students make sense of their findings from the Explore phase, integrating them into a coherent understanding. This phase often includes discussions, presentations, and the use of visual aids to support conceptual clarification (Schneider & Stern, 2010).
- Elaborate: The Elaborate phase extends students' understanding by applying their new knowledge to novel situations. Students are encouraged to use their insights to solve more complex problems, make connections to other topics, and explore further applications of the concepts learned. This phase promotes higher-order thinking by challenging students to think critically and creatively about how their new knowledge applies to different contexts. It supports the transfer of learning, which is essential for deeper learning and problem-solving (Hattie, 2009).
- Evaluate: The Evaluate phase involves assessing students' understanding and learning progress. This phase includes various forms of assessment, such as self-assessments, peer reviews, quizzes, and teacher evaluations. The aim is to gauge how well students have grasped the concepts and to provide feedback for further improvement. Evaluations can be formative, occurring throughout the learning process to inform instruction, or summative, providing a summary of students' achievements at the end of a unit (Black & Wiliam, 1998).

Empirical research supports the effectiveness of the 5E model in improving student outcomes. Artun and Costu (2014) found that the model significantly enhances students' conceptual understanding and promotes critical thinking skills. Their study highlighted how the 5E model supports deep learning by engaging students in active problem-solving and reflection. Similarly, Gokalp and Adam (2020) demonstrated that the 5E model positively impacts students' ability to apply scientific principles and solve complex problems. Their research indicated that the model helps students develop a more profound understanding of scientific concepts and improves their ability to transfer knowledge to new situations.

Despite these successes, there is a notable gap in research regarding the long-term effects of the 5E model, especially within gender-specific STEM programs. The sustainability of the model's benefits over time, particularly in regions with distinct educational and cultural contexts like Northern Nigeria, requires further investigation. Studies focusing on the long-term impact of the 5E model on students' ongoing engagement and success in STEM fields are essential for understanding its potential to support sustained educational equity and excellence (Suwito et al., 2020). Such research could provide valuable insights into how the 5E model can be adapted and optimized to address specific educational challenges and promote gender equity in STEM education.

1.4 Girls For Education and Health Project (G4e&H)

The Girls for Education and Health Project (G4E&H), initiated by the Centre for Girl-child Education (CGE), is a targeted initiative aimed at reducing gender disparities in STEM education and health professions in Northern Nigeria. The project's primary focus is to enhance educational outcomes and career opportunities for rural girls by providing comprehensive academic support in STEM subjects and integrating innovative pedagogical strategies such as the 5E Instructional Model (CGE Report, 2024). This model, developed by the Biological Science Curriculum Study (BSCS) in 1987, is designed to foster inquiry-based learning through five key phases: Engage, Explore, Explain, Elaborate, and Evaluate.

The G4E&H project utilizes the 5E model to create an engaging and effective learning environment. The engage phase captures students' interest by presenting intriguing problems and scenarios that connect to their prior knowledge. In the explore phase, students engage in hands-on activities and experiments to investigate and gather data, fostering active learning and conceptual understanding. The explain phase involves formal instruction where teachers and mentors help students articulate and formalize their findings, while the elaborate phase extends learning by applying new knowledge to complex problems and real-world contexts. Finally, the evaluate phase assesses students' understanding and provides feedback for further improvement (Kayode & Dokme, 2022).

The project’s approach has shown significant success in enhancing students' academic achievements and engagement in STEM subjects. Evidence from the project indicates improved test scores, increased interest in STEM careers, and higher rates of school retention and completion among participating students. This success is attributed to the integration of the 5E model, which has been shown to improve conceptual understanding and critical thinking skills

(Artun & Costu, 2014; Gokalp & Adam, 2020). The 5E model's emphasis on interactive and experiential learning has been instrumental in making STEM education more accessible and relevant for rural girls.

Despite these achievements, the long-term impact of the G4E&H project, particularly the sustained effects of the 5E strategy on students' tertiary education experiences, remains underexplored. While initial outcomes are promising, further research is needed to assess how these benefits translate into students continued academic and professional success beyond secondary education. Investigating the long-term influence of the 5E model on students' performance in tertiary institutions and their career trajectories will provide valuable insights into the program's efficacy and sustainability (Suwito et al., 2020). Future research should focus on several key areas to fully understand the impact of the G4E&H project. These include evaluating the long-term academic success of students, examining the career outcomes of graduates, and exploring factors that contribute to the sustainability of the program's benefits over time. Understanding these aspects will help in optimizing the project's strategies and ensuring its continued effectiveness in bridging the gender gap in STEM education and health professions.

The Girls for Education and Health Project represent a crucial effort to address gender disparities in Northern Nigeria's STEM and health sectors. By leveraging the 5E Instructional Model and providing targeted support, the project has made significant strides in improving educational outcomes and career prospects for rural girls. Continued research and evaluation are essential to understanding the long-term impacts of the project and ensuring its ongoing success and expansion.

2. Methodology

The study adopted the descriptive survey research design. The population of the study comprised all the 450 follow-up girls who participated in the Girls for Education and Health Project in Zaria Local Government Area, Kaduna State, and now undergoing tertiary education programmes in STEM fields. Purposive sampling technique was used to select four tertiary institutions in Zaria Local Government Area, Kaduna State namely: Ahmadu Bello University, Zaria, Federal College of Education, Zaria, College of Health Science, Makarfi, and Zaria Institute of Information Technology, Kaduna State. Simple random sampling technique was used to select 100 respondents; 25 from each of the institutions. The data collection instrument used was a structured questionnaire. The questionnaire had four major sections. Section A sought for the respondents' demographic information. Sections B, C and D were a modified Likert scale with four options of Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). Section B had five items intended to ascertain the follow-up girls' career aspirations in STEM fields in tertiary institutions. Section C had five items aimed at gauging the follow-up girls' academic achievements in STEM fields in tertiary institutions. Section D, with five items, intended to determine the follow-up girls' health practices in tertiary institutions. One hundred copies of the questionnaire were produced and distributed by the researcher and three other research assistants. Retrieval of the questionnaire was on the spot. However, only 98 copies were retrieved. Two copies were not traceable as at the point of recollection. Data from the retrieved questionnaire were analysed using mean and standard deviation. A mean score of 2.5 (the average of a 4 point modified Likert type scale) was set as the decision mark for deciding whether each statement in the relevant sections of the questionnaire was accepted or not. Any statement with a mean score 2.5 or less was deemed "Disagree" while any statement with a mean score above 2.5 was deemed "Agree". All the three research questions were answered using the descriptive mean and standard deviation.

3. Results

The research questions were answered in the order they were raised in the study.

Research Question One: what are the long-term effects of the 5E Model on the follow-up girls' career aspirations in STEM fields in tertiary institutions in Kaduna State?

Data in Table 1 shows that majority of the follow-up girls agreed with all the items on the long-term effects of the 5E Model This result showed that 5E strategy has had long term effects on the participants' career aspirations in STEM fields in tertiary institutions in Kaduna State.

Research Question Two: does the 5E Model have long-term effects on the follow up girls' academic achievements in STEM fields in tertiary institutions in Kaduna State?

The data in Table 2 revealed that majority of the follow-up girls agreed with all the items on the long-term effects of the 5E Model This proved that the 5E Model has sustained effects on the follow-up girls' academic achievements in tertiary institutions in Kaduna State.

Research Question Three: what are the long-term effects of the 5E Model on the follow-up girls' health practices in tertiary institutions in Kaduna State?

Data from Table 3 depicts that majority of the follow-up girls agreed with all the items on the long-term effects of the 5E Model on health practices. This result shows that the 5E Model has had lasting effects on the follow-up girls' health practices in tertiary institutions in Kaduna State.

Table 1: Long Term Effects of 5E Model on Career Aspirations

S/N	Items	N	Mean	SD	Decision
1.	I am still being guided by the STEM career goals I set for myself earlier while participating in Girls for Education and Health Project.	98	2.92	.83	Agree
2.	I establish a network with professionals in STEM fields while in tertiary institution	98	2.61	.74	Agree
3.	Immediately I got admitted into the tertiary level of education, I created a STEM-based career development plan	98	2.93	.73	Agree
4.	Since participating in Girls for Education and Health Project's trainings while in secondary	98	3.18	.87	Agree

5.	school, I have been learning new skills in STEM fields up to today. Here, at the tertiary level, some of my lecturers serve as my mentors; guiding me on how best to navigate the STEM fields for my overall career development	98	3.18	.75	Agree

Table 2: Long-Term Effects of 5E Strategy on Academic Achievement

S/N	**Items**	**N**	**mean**	**SD**	**Decision**
6.	I am satisfied that my academic achievement so far is in commensurate with the academic goals I earlier set for myself while participating in Girls for Education and Health Project	98	3.51	.72	Agree
7.	Every day, I have a study schedule	98	2.64	.58	Agree
8.	I am regular at classes	98	2.66	.97	Agree
9.	I am an active participant in all class discussions and collaborative activities	98	2.66	.92	Agree
10.	I learn in STEM fields outside the lecture halls	98	2.66	9.2	Agree

Table 3: Long Term Effects of 5E Strategy on Health Practices

S/N	**Items**	**N**	**Mean**	**SD**	**Decision**
11.	My participation in the activities of Girls for Education and Health Project has exposed me to understanding situations that are prone to gender-based violence, and to stay away from them.	98	2.66	.92	Agree
12.	I stay physically active and maintain a healthy lifestyle	98	2.64	.58	Agree
13.	I know very well about menstrual hygiene	98	2.66	.97	Agree
14.	I am aware of HIV/AIDS and all the preventive measures.	98	2.61	.74	Agree
15.	I have positive attitude towards family planning and contraception	98	3.18	.75	Agree

Benchmark: $\times \leq 2.5$

4. Discussion

This is a follow-up study which examined the long-term effects of 5E Model of Girls for Education and Health Project in tertiary institutions in Zaria Local Government Area, Kaduna State. The research questions were answered. Findings relating to Research Question One showed that a majority of the follow-up girls believed that the 5E Model they had been introduced to earlier in secondary schools by GEHP still had significant positive influence on their STEM career aspirations. This finding is in conformity with the finding of Akudolu (2005) who also discovered that integrating STEM into learning circle of 5E model can support students' career aspirations, increase motivation to learn, and increase interest in STEM fields.

Moreover, data for Research Question Two revealed that in terms of academic achievement, the follow-up girls agreed that the 5E Model they were exposed to at the secondary school level had still positively impacted on their academic achievements while in tertiary institutions. This finding revealed that the STEM academic goals set up by the follow-up girls were proportionate to their academic achievements while still in tertiary institutions. This finding concurs with the result of Rahma & Ida (2017) that significant STEM approach to Learning Circle 5E can increase learners' understanding of concepts in STEM fields, and increase their ability to interpret, infer, compare and explain concepts in STEM fields.

Furthermore, data for Research Question Three showed that the respondents agreed that their experiences of the 5E Model still had relevance to their personal hygiene and health awareness while in tertiary institutions. This implied that for a successful learning in STEM fields, the follow-up girls still maintained positive health habits and practices. This finding confirms the result of Unlu & Dokme (2022) that majority of the studies carried out using the 5E Model were in the field of science. The reason they advanced was that science topics were related to daily life such as a person's daily lifestyle and health practices/habits. This implies that 5E model is ideal for science subjects on one hand, and for learners' health habits, on the other hand.

5. Conclusion

This follow-up study on the long-term effects of the 5E Model of Girls for Education and Health Project in Zaria, Kaduna State, provided empirical evidence of the effectiveness of 5E Model in STEM education. The study proved that innovative STEM education could be enhanced through the 5E Model. The findings confirmed significant and sustained improvements in the follow-up girls' career aspirations, academic achievements and personal health practices. By implication, innovative STEM education via the 5E Model can bridge the gender gap in STEM fields and foster a pipeline of female leaders in science and technology.

6. Recommendations

Based on the findings and the conclusion, it is recommended that:

a. Girls for Education and Health Project should expand the domains of their activities to encompass the whole northern states of Nigeria in order to provide similar opportunities to rural girls in all the non-participating states.

b. A similar project should be constituted at the basic education level with the aim of supporting innovative STEM education right from the foundational levels.
c. A longitudinal study should be carried out to track the follow-up girls over an extended period to assess the sustained impacts of the 5E Model.
d. Policy makers should create enabling environments for increasing gender participation in STEM fields and STEM workforce in Nigeria.

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Article 4

Calculating Mean, Variance, Standard Deviation and Mode Using the Difference in Frequency and Data

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Abstract

The purpose of this conceptual paper is to offer the alternative methods in statistics for calculating mean, variance, standard deviation and mode. It involves the use of half of the difference in frequency (Df = $\frac{f_{n-}f_1}{2}$) alongside half of the difference in data (Dx = $\frac{X_{n-}X_1}{2}$). Based on my literature review, the difference in the frequency (Df) and data (Dx) has never been utilized to solve problems in statistics and mathematics at large. Therefore, this conceptual paper will fully explain how the difference in frequency of data set alongside the difference in data can be used to calculate the mean, variance, standard deviation and analyzing data. Starting with data of same frequency and followed by varying the frequencies of same data steadily, a pattern in solutions was discovered based on the difference in frequency. This is the pattern that helped me to invent the methods discussed here. The results indicated that only problems of grouped data with constant interval and ungrouped data with common difference between data sets($X_{1,}$ $X_{2,}$ $X_{3\,...}$ Xn) agrees or can be solved using the methods I have invented. This study definitely and without any absolute error answers the questions regarding the named problems by using the difference in frequency (Df) and data (Dx).

Keywords: Mean; variance; standard deviation; mode; grouped data; difference in frequency (Dx), difference in data (Df),

1. Introduction

1.1. Background: According to Dass H.K. Advanced Engineering Mathematics. Chapter 10, Statistics (pp. 735 – 742) Statistics is defined as a branch of science dealing with the collection of data, organizing, summarizing, presenting and analyzing data and drawing valid conclusions and thereafter making reasonable decisions on the basis of such analysis. Statistics has been one of the most important Mathematical topics in our daily life. Many different fields use the knowledge of statistics such as banks, census, insurance companies, engineering, in medicine and so on. Basically, this research paper shall concentrate on three problems in statistics such as mean, variance, standard deviation and analyzing data using Musonda's factor$\left(\mathrm{M} = \frac{\mathrm{DxDf}}{\Sigma \mathrm{f}}\right)$.

2. Literature review

There are so many types of methods that are been used to solve different Statistical problems such as the mean, variance, standard deviation and so on. Among the methods other researchers have worked on or invented are mainly concerned with the

usage of the difference in data, data with mean etc. Some of the already working methods or formulas are:

$$\text{Mean} = \frac{F_1X_1 + F_2X_2 + F_3X_3 ... + F_nX_n}{F_1+F_2+F_3+\cdots+F_n} = \frac{\Sigma fx}{\Sigma f}$$

$$\text{Variance} = \frac{F_1(X_1)^2+F_2(X_2)^2+F_3(X_3)^2+\cdots F_n(X_n)^2}{F_1+F_2+F_3+\cdots+F_n} - \left(\frac{\Sigma fx}{\Sigma f}\right)^2 = \frac{\Sigma fx^2}{\Sigma f} - \left(\frac{\Sigma fx}{\Sigma f}\right)^2$$

$$\text{Standard deviation} = \sqrt{variance} = \sqrt{\frac{\Sigma fx^2}{\Sigma f} - \left(\frac{\Sigma fx}{\Sigma f}\right)^2}$$

In the assumed mean method, a term **a** from data set is selected as assumed mean and it is subtracted from the rest of terms from data set to obtain the difference **d.** The differences obtained is multiplied by its corresponding frequencies. The assumed mean **a** is added to the sum of products of frequency and product **fd** divided by sum of frequency as shown below

$$\text{Mean} = \mathbf{a} + \frac{F_1(X_1-a)+F_2(X_2-a)+F_3(X_3-a)+\cdots+F_n(X_n-a)}{f1+f2+f3+\cdots+fn} = \mathbf{a} + \frac{\Sigma fd}{\Sigma f}$$

To find variance the sum of frequency multiplied by d is subtracted from the sum of frequency multiplied by d squared is

$$\sigma^2 = \frac{F_1(X_1-a)^2+F_2(X_2-a)^2+F_2(X_2-a)^2+F_3(X_3-a))^2+F_n(X_n-a))^2}{f1+f2+f3+\cdots+fn} - \left(\frac{\Sigma fd}{\Sigma f}\right)^2 = \frac{\Sigma fd^2}{\Sigma f} - \left(\frac{\Sigma fd}{\Sigma f}\right)^2$$

$$\text{Standard deviation} = \sqrt{variance} = \sqrt{\frac{\Sigma fd^2}{\Sigma f} - \left(\frac{\Sigma fd}{\Sigma f}\right)^2}$$

Other examples of methods for calculating mean, variance and standard deviation includes the following:

For the ungrouped data set these methods are used Mean = $\frac{\sum x}{n}$, Variance = $\frac{\sum(x-\bar{x})^2}{n}$ or $\frac{\sum x^2}{n} - (\bar{x})^2$, Standard deviation = $\sqrt{\frac{\sum(x-\bar{x})^2}{n}}$ or $\sqrt{\frac{\sum x^2}{n} - (\bar{x})^2}$ and for grouped data set we also use

Variance = $\frac{\sum f(x-\bar{x})^2}{\sum f}$ or $\frac{\sum fx^2}{\sum f} - (\bar{x})^2$ Standard deviation = $\sqrt{\frac{\sum f(x-\bar{x})^2}{\sum f}}$ or $\sqrt{\frac{\sum fx^2}{\sum f} - (\bar{x})^2}$

2.1 Research Gap: Based on the background information above, all methods above have been agreed upon in our mathematics literature. According to my investigation i conducted based on literature review, it shows that for so many years, there has never been any study that indicates how the difference in frequency (Df) of data alongside the difference in data (Dx) can be used to solve statistical problems such as finding the mean, variance and standard deviation. This particular gap of using difference in frequency (Df) and data (Dx) needs filling because it may aid researchers to invent many other kinds of methods/formulas to solve various problems in statistics and mathematics.

2.2. Research objectives

The primary objective of the mentioned methods is to enhance accuracy and simplicity of calculating mean, variance and standard deviation. The key goals are:

1. To increase the simplicity by simplifying the implementation of statistical calculations by utilizing novel formulas that reduces the complexity of operations.
2. To offer practical benefits for data analysis in many areas such as statistics, data science, and research by providing tools that are user friendly and effective.
3. To contribute to theoretical understanding of statistical measures by presenting new approaches that could lead to further developments in statistical theory.

2.3 Scope: This work will contribute to the body of knowledge in solving the named statistics problems. The methods invented here solves problems for both grouped and ungrouped data with constant interval and constant difference among data sets $X_{1,}$ $X_{2,\ldots}$ X_n respectively. For all data set that are in the form stated here, the mean, variance and standard deviation can be calculated without any absolute error. However, the methods fails to solve problems without constant intervals and constant difference among data. It leaves out an absolute error.

3. Methodology

The first term X_1 is subtracted from last term X_n and the difference is divided by two to get Dx. The second first term is also subtracted from the second last term and the subtraction continues until to the last middle term(s) in data set. The same is also done on frequency; the first frequency f_1 is subtracted from the last frequency f_n to obtain Df the second frequency is also subtracted from the second last term and this process is repeated like what is done on data.

Below is an illustration demonstrating how I invented the methods of calculating mean, variance and standard deviation.

Musonda's statistical factor

The Musonda's statistical factor is used to calculate the mean, variance, standard deviation and analyzing data. By using the table below, Musonda's factor can be obtained.

Data (x)	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Frequency (f)	f_1	f_2	f_3	f_4	f_5	f_6	f_7

$$M = \frac{1}{\sum f}\left[\left(\frac{f_7 - f_1}{2}\right)\left(\frac{X_7 - X_1}{2}\right) + \left(\frac{f_6 - f_2}{2}\right)\left(\frac{X_6 - X_2}{2}\right) + \left(\frac{f_5 - f_3}{2}\right)\left(\frac{X_5 - X_3}{2}\right) + \left(\frac{f_4 - f_4}{2}\right)\left(\frac{X_4 - X_4}{2}\right)\right]$$

$$\mathrm{M} = \frac{1}{\sum f}\left[(D_{1f})(D_{1x}) + (D_{2f})(D_{2x}) + (D_{3f})(D_{3x}) + (D_{4f})(D_{4x})\right]$$

$$\mathrm{M} = \frac{1}{\sum f}\left[\sum D_f D_x\right]$$

$$\mathbf{M} = \frac{\sum \boldsymbol{D_f D_x}}{\sum \boldsymbol{f}} \quad \text{or } \mathbf{M} = \overline{\boldsymbol{X}} - \frac{1}{2}(\boldsymbol{X_1} + \boldsymbol{X_n})$$

Calculating Mean using Musonda's Statistical Factor

Where $\bar{x}$ = mean

a = mid value of data = $\frac{Xn+X_1}{2}$

Dx = half difference in data = $\frac{Xn-X_1}{2}$

Df = half difference in frequency = $\frac{f_n - f_1}{2}$

$\sum f$ = summation frequency.

$$\overline{X} = \frac{X_n + X_1}{2} + \frac{1}{\sum f}\left[\left(\frac{f_n - f_1}{2}\right)\left(\frac{X_n - X_1}{2}\right) + \left(\frac{f_{n-1} - f_2}{2}\right)\left(\frac{X_{n-1} - X_2}{2}\right) + \left(\frac{f_{n-2} - f_3}{2}\right)\left(\frac{X_{n-2} - X_3}{2}\right) + \cdots\right]$$

$$\overline{X} = \mathrm{a} + \frac{1}{\sum f}\left[(D_{f1})(D_{x1}) + (D_{f2})(D_{x2}) + (D_{f3})(D_{x3}) \ldots + \right]$$

$$\overline{X} = \mathrm{a} + \frac{1}{\sum f}\left(\sum D_f D_x\right)$$

$$\boldsymbol{\overline{X}} = \mathbf{a} + \frac{\sum \boldsymbol{D_f D_x}}{\sum \boldsymbol{f}}$$

Proving the mean formula

Prove that $\mathbf{a} + \frac{\sum \boldsymbol{D_f D_x}}{\sum \boldsymbol{f}} = \frac{\sum \boldsymbol{fx}}{\sum \boldsymbol{f}}$

Let $\mathbf{a} = \boldsymbol{X_3}$ and use the table below to prove.

X	F	D_x	D_f	$D_x D_f$	$f{D_x}^2$
X_1	F_1	$\frac{X_5 - X_1}{2}$	$\frac{F_5 - F_1}{2}$	$\left(\frac{X_5 - X_1}{2}\right)\left(\frac{F_5 - F_1}{2}\right)$	$f_1\left(\frac{X_5 - X_1}{2}\right)^2$
X_2	F_2	$\frac{X_4 - X_2}{2}$	$\frac{F_4 - F_2}{2}$	$\left(\frac{X_4 - X_2}{2}\right)\left(\frac{F_4 - F_2}{2}\right)$	$f_2\left(\frac{X_4 - X_2}{2}\right)^2$
X_3	F_3	0	0	0	0
X_4	F_4	$\frac{X_4 - X_2}{2}$	$\frac{F_4 - F_2}{2}$	$\left(\frac{X_4 - X_2}{2}\right)\left(\frac{F_4 - F_2}{2}\right)$	$f_4\left(\frac{X_4 - X_2}{2}\right)^2$
X_5	F_5	$\frac{X_5 - X_1}{2}$	$\frac{F_5 - F_1}{2}$	$\left(\frac{X_5 - X_1}{2}\right)\left(\frac{F_5 - F_1}{2}\right)$	$f_5\left(\frac{X_5 - X_1}{2}\right)^2$
Total	$\sum f$			$\sum D_x D_f$	$\sum f{D_x}^2$

$$\mathbf{X_3} + \frac{\sum \boldsymbol{DxDf}}{\sum \boldsymbol{f}} = \frac{\sum \boldsymbol{fx}}{\sum \boldsymbol{f}}$$

$$X_3 + \frac{\left(\frac{F5-F1}{2}\right)\left(\frac{X5-X1}{2}\right)+\left(\frac{F4-F2}{2}\right)\left(\frac{X4-X2}{2}\right)+\left(\frac{F4-F2}{2}\right)\left(\frac{X4-X2}{2}\right)+\left(\frac{F5-F1}{2}\right)\left(\frac{X5-X1}{2}\right)}{\sum f} = \frac{\sum fx}{\sum f}$$

$$X3 + \frac{(F_5-F_1)(X_5-X_1)+(F_4-F_2)(X_4-X_2)}{2\sum f} = \frac{\sum fx}{\sum f}$$

$$X_3 + \frac{F_5X_5-F_5X_1-F_1X_5+F_1X_1+F_4X_4-F_4X_2-F_2X_4+F_2X_2}{2\sum f} = \frac{\sum fx}{\sum f}$$

$$\frac{X3}{1} + \frac{F_1X_1+F_2X_2+F_4X_4+F_5X_5-F_5X_1-F_1X_5-F_4X_2-F_2X_4}{2\sum f} = \frac{\sum fx}{\sum f}$$

$$\frac{2\sum fX3+F_1X_1+F_2X_2+F_4X_4+F_5X_5-F_5X_1-F_1X_5-F_4X_2-F_2X_4}{2\sum f} = \frac{\sum fx}{\sum f}$$

$$\frac{2X_3(F_1+F_2+F_3+F_4+F_5)+F_1X_1+F_2X_2+F_4X_4+F_5X_5-F_5X_1-F_1X_5-F_4X_2-F_2X_4}{2\sum f} = \frac{\sum fx}{\sum f}$$

$$\frac{2F_1X_3 + 2F_2X_3 + 2F_3X_3 + 2F_4X_3 + 2F_5X_3 + F_1X_1 + F_2X_2 + F_4X_4 + F_5X_5 - F_5X_1 - F_1X_5 - F_4X_2 - F_2X_4}{2\sum f}$$

$$= \frac{\sum fx}{\sum f}$$

$$\frac{F_1X_1 + F_2X_2 + 2F_3X_3 + F_4X_4 + F_5X_5 + 2F_1X_3 + 2F_2X_3 + 2F_4X_3 + 2F_5X_3 - F_5X_1 - F_1X_5 - F_4X_2 - F_2X_4}{2\sum f}$$

$$= \frac{\sum fx}{\sum f}$$

$$2F_2X_3 + 2F_4X_3 - F_4X_2 - F_2X_4 = \boldsymbol{F_2X_2 + F_4X_4}$$

$$2F_1X_3 + 2F_5X_3 - F_5X_1 - F_1X_5 = \boldsymbol{F_1X_1 + F_5X_5}$$

$$\frac{F_1X_1 + F_2X_2 + 2F_3X_3 + F_4X_4 + F_5X_5 + 2F_2X_3 + 2F_4X_3 - F_4X_2 - F_2X_4 + 2F_1X_3 + 2F_5X_3 - F_5X_1 - F_1X_5}{2\sum f}$$

$$= \frac{\sum fx}{\sum f}$$

$$\frac{F_1X_1 + F_2X_2 + 2F_3X_3 + F_4X_4 + F_5X_5 + F_2X_2 + F_4X_4 + F_1X_1 + F_5X_5}{2\sum f} = \frac{\sum fx}{\sum f}$$

$$\frac{2F_1X_1 + 2F_2X_2 + 2F_3X_3 + 2F_4X_4 + 2F_5X_5}{2\sum f} = \frac{\sum fx}{\sum f}$$

$$\frac{2(F_1X_1 + F_2X_2 + F_3X_3 + F_4X_4 + F_5X_5)}{2\sum f} = \frac{\sum fx}{\sum f}$$

$$\frac{F_1X_1 + F_2X_2 + F_3X_3 + F_4X_4 + F_5X_5}{\sum f} = \frac{\sum fx}{\sum f}$$

$$\frac{\sum \boldsymbol{fx}}{\sum \boldsymbol{f}} = \frac{\sum \boldsymbol{fx}}{\sum \boldsymbol{f}} \quad \textbf{Proven}$$

Calculating Variance using Musonda's statistical factor

The Musonda's statistical factor $(\frac{\sum \boldsymbol{DxDf}}{\sum \boldsymbol{f}})$ is used to derive the new formula for calculating variance.

Below are steps for the derivation of the new formula for calculating variance by using the **difference in frequency**

$$\sigma^2 = \frac{1}{\sum f}\left[f_1\left(\frac{X_n - X_1}{2}\right)^2 + f_2\left(\frac{X_{n-1} - X_2}{2}\right)^2 + f_3\left(\frac{X_{n-2} - X_3}{2}\right)^2 + \cdots\right]. - \frac{1}{\sum f}\left[\left(\frac{f_n - f_1}{2}\right)^2\left(\frac{X_n - X_1}{2}\right)^2 + \left(\frac{f_{n-1} - f_2}{2}\right)^2\left(\frac{X_{n-1} - X_2}{2}\right)^2 + \left(\frac{f_{n-2} - f_3}{2}\right)^2\left(\frac{X_{n-2} - X_3}{2}\right)^2 + \cdots\right]$$

$$\sigma^2 = \frac{1}{\sum f}\left[f_1(D_{1x})^2 + f_2(D_{2x})^2 + f_3(D_{3x})^2 + \cdots\right]. - \frac{1}{\sum f}\left[\left(D_{1f}\right)^2(D_{1x})^2 + \left(D_{2f}\right)^2(D_{2x})^2 + \left(D_{3f}\right)^2(D_{3x})^2 + \cdots\right]$$

$$\sigma^2 = \frac{1}{\sum f}[\, f_1(D_{1x})^2 + f_2(D_{2x})^2 + f_3(D_{3x})^2] - \frac{1}{\sum f}\left[\left(D_{1f}D_{1x}\right)^2 + \left(D_{2f}D_{2x}\right)^2 + \left(D_{3f}D_{3x}\right)^2 + \dots\right]$$

$$\sigma^2 = \frac{1}{\sum f}[\sum f(D_x)^2] - \frac{1}{\sum f}\left[\sum\left(D_f D_x\right)^2\right]$$

$$\boldsymbol{\sigma^2 = \frac{\sum f(D_x)^2}{\sum f} - \left(\frac{\sum D_f D_x}{\sum f}\right)^2}$$

By using the information in the table below, prove that

$$\frac{\sum f(D_x)^2}{\sum f} - \left(\frac{\sum D_x D_f}{\sum f}\right)^2 = \frac{\sum f x^2}{\sum f} - \left(\frac{\sum f x}{\sum f}\right)^2$$

Data (x)	X_1	X_2	X_3
Frequency (f)	F_1	F_2	F_3

Let Dx = $\frac{X_3 - X_1}{2}$, and Df = $\frac{F_3 - F_1}{2}$.

$$\frac{\sum f(Dx)^2}{\sum f} - \left(\frac{\sum DxDf}{\sum f}\right)^2 = \frac{\sum \mathrm{fx}^2}{\sum \mathrm{f}} - \left(\frac{\sum \mathrm{fx}}{\sum \mathrm{f}}\right)^2$$

$$\frac{F_1(D_{1x})^2 + F_3(D_{3x})^2}{\sum f} - \left(\frac{D_{1x}D_{1f} + D_{3x}D_{3f}}{\sum f}\right)^2 = \frac{\sum \mathrm{fx}^2}{\sum \mathrm{f}} - \left(\frac{\sum \mathrm{fx}}{\sum \mathrm{f}}\right)^2$$

$$= \frac{F_1\left(\frac{X_3 - X_1}{2}\right)^2 + F_3\left(\frac{X_3 - X_1}{2}\right)^2}{\sum \mathrm{f}} - \left[\frac{\left(\frac{F_3 - F_1}{2}\right)\left(\frac{X_3 - X_1}{2}\right) + \left(\frac{F_3 - F_1}{2}\right)\left(\frac{X_3 - X_1}{2}\right)}{\sum \mathrm{f}}\right]^2$$

$$= \frac{\frac{F_3\left(X_3{}^2 - 2X_1X_3 + X_1{}^2\right) + F_3\left(X_3{}^2 - 2X_1X_3 + X_1{}^2\right)}{4}}{\sum \mathrm{f}} - \left[\frac{(F_3 - F_1)(X_3 - X_1)}{\sum \mathrm{f}}\right]^2$$

$$= \frac{\frac{\left(F_1X_3{}^2 - 2F_1X_1X_3 + F_1X_1{}^2\right) + \left(F_3X_3{}^2 - 2F_3X_1X_3 + F_3X_1{}^2\right)}{4}}{\sum \mathrm{f}} - \left[\frac{(F_3 - F_1)(X_3 - X_1)}{\sum \mathrm{f}}\right]^2$$

$$= \frac{\left(F_1X_3{}^2 - 2F_1X_1X_3 + F_1X_1{}^2\right) + \left(F_3X_3{}^2 - 2F_3X_1X_3 + F_3X_1{}^2\right)}{4\sum \mathrm{f}} - \frac{\left[\left(F_3{}^2 - 2F_1F_3 + F_1{}^2\right)\left(X_3{}^2 - 2X_1X_3 + X_1{}^2\right)\right]}{4\sum f^2}$$

$$= \frac{\sum \mathrm{f}\left(F_1X_3{}^2 - 2F_1X_1X_3 + F_1X_1{}^2\right) + \sum \mathrm{f}\left(F_3X_3{}^2 - 2F_3X_1X_3 + F_3X_1{}^2\right) - \left[\left(F_3{}^2 - 2F_1F_3 + F_1{}^2\right)\left(X_3{}^2 - 2X_1X_3 + X_1{}^2\right)\right]}{4\sum f^2}$$

$$= \frac{(F_1 + F_2 + F_3)\left(F_1X_3{}^2 - 2F_1X_1X_3 + F_1X_1{}^2\right) + (F_1 + F_2 + F_3)\left(F_3X_3{}^2 - 2F_3X_1X_3 + F_3X_1{}^2\right) - \left[\left(F_3F_3X_3{}^2 - 2F_3X_1F_3X_3 - F_3F_3X_1{}^2 - 2F_1F_3X_3{}^2 + 4F_1X_1F_3X_3 - 2F_3F_1X_1{}^2 + F_1F_1X_3{}^2 - 2F_1X_1F_1 + F_1F_1X_1{}^2\right)\right]}{4\sum f^2}$$

$$= \frac{\left(F_1F_1{X_3}^2 - 2F_1X_1F_1X_3 + F_1F_1{X_1}^2 + F_1F_2{X_3}^2 - 2F_1X_1F_2 + F_2F_1{X_1}^2 + F_1F_3{X_3}^2 - 2F_1X_1F_3X_3 + F_3F_1{X_1}^2\right) + \left(F_1F_3{X_3}^2 - 2F_1X_1F_3X_3 + F_3F_1{X_1}^2 + F_2F_3{X_3}^2 - 2F_3X_3F_2X_1 + F_2F_3{X_1}^2 + F_3F_3{X_3}^2 - 2F_3X_1F_3X_3 + F_3F_3{X_1}^2\right) - \left[\begin{pmatrix} F_3F_3{X_3}^2 - 2F_3X_1F_3X_3 - F_3F_3{X_1}^2 - 2F_1F_3{X_3}^2 + 4F_1X_1F_3X_3 - 2F_3F_1{X_1}^2 + F_1F_1{X_3}^2 - 2F_1X_1F_3X_3 \\ +F_1F_1{X_1}^2 \end{pmatrix}\right]}{4\sum f^2}$$

$$= \frac{\left(F_1F_3{X_3}^2 - 2F_1X_1F_1X_3 + F_1F_1{X_1}^2 + F_1F_2{X_3}^2 - 2F_1X_1F_2X_3 + F_2F_1{X_1}^2 + F_1F_3{X_3}^2 - 2F_1X_1F_3X_3 + F_3F_1{X_1}^2\right) + \left(F_1F_3{X_3}^2 - 2F_1X_1F_3X_3 + F_3F_1{X_1}^2 + F_2F_3{X_3}^2 - 2F_3X_3F_2X_1 + F_2F_3{X_1}^2 + F_3F_3{X_3}^2 - 2F_3X_1F_3X_3 + F_3F_3{X_1}^2\right) - \left[\begin{pmatrix} F_3F_3{X_3}^2 - 2F_3X_1F_3X_3 - F_3F_3{X_1}^2 - 2F_1F_3{X_3}^2 + 4F_1X_1F_3X_3 - 2F_3F_1{X_1}^2 + F_1F_1{X_3}^2 - 2F_1X_1F_1X_3 \\ +F_1F_1{X_1}^2 \end{pmatrix}\right]}{4\sum f^2}$$

$$= \frac{F_1F_3{X_3}^2 + 4F_3F_1{X_1}^2 - 8F_1X_1F_3X_3 + F_2F_1{X_1}^2 + F_2F_3{X_3}^2 + F_2F_3{X_1}^2 + F_1F_2{X_3}^2 - 2F_3X_3F_2X_1 - 2F_1X_1F_2X_3}{4\sum f^2}$$

Take note of the following:

(1) $(F_1X_1 + F_3X_3)^2 = F_1F_1{X_1}^2 + 2F_1X_1F_3X_3 + F_3F_3{X_3}^2$

$- 2F_1X_1F_3X_3 = F_1F_1{X_1}^2 + F_3F_3{X_3}^2 - (F_1X_1 + F_3X_3)^2$

Now multiply by 4 through out to obtain $-8F_1X_1F_3X_3$

$$-8F_1X_1F_3X_3 = 4F_1F_1{X_1}^2 + 4F_3F_3{X_3}^2 - 4(F_1X_1 + F_3X_3)^2$$

(2) $F_1X_3F_2X_3 = F_1X_3(2F_2X_2 - F_2X_1)$ *from the identity* $F_2X_1 + F_2X_3 = 2F_2X_2$

$= 2F_1X_2F_2X_3 - F_1X_1F_2X_3$

$= 2F_1X_2(2F_2X_2 - F_2X_1) - F_1X_1(2F_2X_2 - F_2X_1)$

$= 4F_1F_2{X_2}^2 - 2F_1X_1F_2X_2 - 2F_1X_1F_2X_2 - F_2F_1{X_1}^2$

$= 4F_1F_2{X_2}^2 - 4F_1X_1F_2X_2 - F_2F_1{X_1}^2$

$= 4F_1F_2{X_2}^2 + 2F_1F_1{X_1}^2 + 2F_2F_2{X_2}^2 + F_2F_1{X_1}^2 - 2(F_1X_1 + F_2X_2)^2$

(3) $F_3X_1F_2X_1 = F_3X_1(2F_2X_2 - F_2X_3)$ *from the identity* $F_2X_1 + F_2X_3 = 2F_2X_2$

$= 2F_3X_2F_2X_1 - F_3X_3F_2X_1$

$= 2F_3X_2(2F_2X_2 - F_2X_3) - F_3X_3(2F_2X_2 - F_2X_3)$

$= 4F_3X_2{X_2}^2 - 2F_2X_2F_3X_3 - 2F_2X_2F_3X_3 + F_2F_3{X_3}^2$

$= 4F_3F_2{X_2}^2 - 4F_2X_2F_3X_3 + F_2F_3{X_3}^2$

$= 4F_3X_2{X_2}^2 + 2F_3F_3{X_3}^2 + 2F_2F_2{X_2}^2 + F_2F_3{X_3}^2 - 2(F_2X_2 + F_3X_3)^2$

(4) -$2F_3X_3F_2X_1$ = -$2F_3X_3$ ($2F_2X_2$ – F_2X_3) *from the identity* $F_2X_1 + F_2X_3 = 2F_2X_2$

$$= -4F_2X_2F_3X_3 + 2F_2F_3{X_3}^2$$

$$= 2F_2F_2{X_2}^2 + 2F_3F_3{X_3}^2 + 2F_2F_3{X_3}^2 - 2(2F_2X_2 + F_2X_3)^2$$

(5) -$2F_1X_1F_2X_3$ = -$2F_1X_1(2F_2X_2 - F_2X_1)$ *from the identity* $F_2X_1 + F_2X_3 = 2F_2X_2$

$$= -4F_1X_1F_2X_2 + 2F_2F_1{X_1}^2$$

$$= 2F_1F_1{X_1}^2 + 2F_2F_2{X_2}^2 + 2F_2F_1{X_1}^2 - 2(F_1X_1 + F_2X_2)^2$$

Now the expression becomes

$$= \frac{\begin{matrix} 4F_1F_3{X_3}^2+4F_3F_1{X_1}^2+4F_1F_1{X_1}^2+4F_3F_3{X_3}^2-4(F_1X_1+F_3X_3)^2+F_2F_1{X_1}^2+ \\ F_3F_3{X_3}^2+4F_3X_2{X_2}^2+2F_3F_3{X_3}^2+2F_2F_2{X_2}^2+F_2F_3{X_3}^2-2(F_2X_2+F_3X_3)^2+ \\ 4F_1F_2{X_2}^2+2F_1F_1{X_1}^2+2F_2F_2{X_2}^2+2F_2F_1{X_1}^2-2(F_1X_1+F_2X_2)^2+4F_3X_2{X_2}^2+ \\ 2F_3F_3{X_3}^2+2F_2F_2{X_2}^2+F_2F_3{X_3}^2-2(F_2X_2+F_3X_3)^2+2F_1F_1{X_1}^2+2F_2F_2{X_2}^2+ \\ 2F_2F_1{X_1}^2-2(F_1X_1+F_2X_2)^2 \end{matrix}}{4\sum f^2}$$

$$\frac{\begin{matrix} 4F_1F_3{X_3}^2 + F_3F_1{X_1}^2 + 8F_1F_1{X_1}^2 + 8F_3F_3{X_3}^2 + 4F_2F_3{X_3}^2 + 4F_3F_2{X_2}^2 + 8F_2F_2{X_2}^2 \\ +4F_1F_2{X_2}^2 + 4F_2F_1{X_1}^2 - 4(F_1X_1 + F_3X_3)^2 - 4(F_1X_1 + F_2X_2)^2 - 4(F_2X_2 + F_3X_3)^2 \end{matrix}}{4\sum f^2}$$

$$= \frac{\begin{matrix} 8F_1F_1{X_1}^2 + 4F_1F_2{X_2}^2 + 4F_1F_3{X_3}^2 + 4F_2F_1{X_1}^2 + 8F_2F_2{X_2}^2 + 4F_2F_3{X_3}^2 + 4F_3F_1{X_1}^2 \\ +4F_3F_2{X_2}^2 + 8F_3F_3{X_3}^2 - 4(F_1X_1 + F_3X_3)^2 - 4(F_1X_1 + F_2X_2)^2 - 4(F_2X_2 + F_3X_3)^2 \end{matrix}}{4\sum f^2}$$

$$= \frac{\begin{matrix} 4F_1F_1{X_1}^2 + 4F_2F_1{X_1}^2 + 4F_3F_1{X_1}^2 + 4F_1F_2{X_2}^2 + 4F_2F_2{X_2}^2 + 4F_3F_2{X_2}^2 \\ +4F_1F_3{X_3}^2 + 4F_2F_3{X_3}^2 + 4F_3F_3{X_3}^2 + 4F_1F_1{X_1}^2 + 4F_2F_2{X_2}^2 + 4F_3F_3{X_3}^2 \\ -4(F_1X_1 + F_3X_3)^2 - 4(F_1X_1 + F_2X_2)^2 - 4(F_2X_2 + F_3X_3)^2 \end{matrix}}{4\sum f^2}$$

$$= \frac{\begin{matrix} F_1{X_1}^2(4F_1 + 4F_2 + 4F_3) + F_2{X_2}^2(4F_1 + 4F_2 + 4F_3) + F_3{X_3}^2(4F_1 + 4F_2 + 4F_3) \\ + 4F_1F_1{X_1}^2 + 4F_2F_2{X_2}^2 + 4F_3F_3{X_3}^2 - 4F_1F_1{X_1}^2 - 8F_1X_1F_3X_3 - 4F_3F_3{X_3}^2 \\ - 4F_1F_1{X_1}^2 - 8F_1X_1F_2X_2 - 4F_2F_2{X_2}^2 - 4F_2F_2{X_2}^2 - 8F_2X_2F_3X_3 - 4F_3F_3{X_3}^2 \end{matrix}}{4\sum f^2}$$

$$= \frac{\begin{matrix} (4F_1 + 4F_2 + 4F_3)\left(F_1{X_1}^2 + F_2{X_2}^2 + F_3{X_3}^2\right) - 4F_1F_1{X_1}^2 - 8F_1X_1F_3X_3 - 4F_3F_3{X_3}^2 \\ -8F_1X_1F_2X_2 - 4F_2F_2{X_2}^2 - 8F_2X_2F_3X_3 \end{matrix}}{4\sum f^2}$$

$$= \frac{4\sum f\left(F_1{X_1}^2 + F_2{X_2}^2 + F_3{X_3}^2\right) - (2F_1X_1 + 2F_2X_2 + 2F_3X_3)^2}{4\sum f^2}$$

$$= \frac{4\sum f\left(F_1{X_1}^2 + F_2{X_2}^2 + F_3{X_3}^2\right)}{4\sum f . \sum f} - \frac{(2F_1X_1 + 2F_2X_2 + 2F_3X_3)^2}{4\sum f^2}$$

$$= \frac{F_1{X_1}^2 + F_2{X_2}^2 + F_3{X_3}^2}{\sum f} - \frac{(2F_1X_1 + 2F_2X_2 + 2F_3X_3)^2}{(2\sum f)^2}$$

$$= \frac{\sum FX^2}{\sum f} - \left(\frac{2F_1X_1 + 2F_2X_2 + 2F_3X_3}{2\sum f}\right)^2$$

$$= \frac{\sum FX^2}{\sum f} - \left(\frac{F_1X_1 + F_2X_2 + F_3X_3}{\sum f}\right)^2$$

$$\frac{\sum FX^2}{\sum f} - \left(\frac{\sum FX}{\sum f}\right)^2 \text{ proven}$$

Calculating Standard Deviation using Musonda's statistical factor

The standard deviation of data given is the square root of variance. Therefore, based on the formula above, standard deviation is calculated as shown below.

$$\sigma = \sqrt{\frac{\sum f(D_x)^2}{\sum f} - \left(\frac{\sum D_f D_x}{\sum f}\right)^2}$$

Identifying Median of Discrete Data by Using Musonda's Statistical Factor

Age (x)	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Frequency (f)	F_1	F_2	F_3	F_4	F_5	F_6	F_7
Limit (k)	-1.5	-1	-0.5	0	0.5	1	1.5

From the table above, we can derive a formula for calculating the median based on limits.

M.R = Musonda's ratio

M = Musonda's statistical factor

D = Common difference for discrete data

$$\text{M.R} = \frac{\text{M}}{\text{D}}$$

$$\text{MEDIAN}_{\text{M.R} \to \text{K}} = \text{X}_\text{n}$$

When Musonda's ratio approaches or equal to Limit (K) i.e $\text{M.R} \to \text{K}$, then the term above that particular K is the median.

4. Results

Below are two examples that are solved using Joseph Musonda's method.

1. The ages of people living at Pamodzi Village are recorded in the frequency table

Data (x)	$0< X \leq 10$	$10< X \leq 20$	$20< X \leq 30$	$30< X \leq 40$	$40< X \leq 50$	$50< X \leq 60$
Frequency (f)	7	22	28	23	15	5

Calculate the following by using Musonda's method

(a) Mean

(b) Variance

(c) Standard deviation

Solutions

Ages	Frequency (f)	X	D_x	D_f	$D_x D_f$	$f D_x{}^2$
$0< X \leq 10$	7	5	25	-1	-25	4375
$10< X \leq 20$	22	15	15	-3.5	-52.5	4950
$20< X \leq 30$	28	25	5	-2.5	-12.5	700
$30< X \leq 40$	23	35	5	-2.5	-12.5	575
$40< X \leq 50$	15	45	15	-3.5	-52.5	3375
$50< X \leq 60$	5	55	25	-1	-25	3125
Total	$\sum f$ =100				$\sum D_x D_f$ =-180	$\sum f D_x{}^2$ =17100

(a) $\bar{x} = \mathbf{a} + \frac{\sum \boldsymbol{DxDf}}{\sum \boldsymbol{f}}$ (b) $^2 = \frac{\sum f(dx)^2}{\sum f} - (\frac{\sum dxdf}{\sum f})^2$ (c) $\sigma = \sqrt{\frac{\sum f(dx)^2}{\sum f} - (\frac{\sum dxdf}{\sum f})^2}$

$= \frac{\mathbf{55+5}}{\mathbf{2}} + \frac{\mathbf{-180}}{\mathbf{100}}$ $= \frac{17100}{100} - (\frac{-180}{(100)})^2$ $= \sqrt{167.76}$

$= 30 - 1.8$ $= 171 - (-1.8)^2$ $=$ **12.95**

$=$ **28.2** $= 171 - 3.24$

$= \mathbf{167.76}$

Example

Below are ages of 60 teachers from Kalumbila district who attended ZAME national meeting in Kitwe in the year 2024.

Age (X)	32	34	36	38	40	42
Frequency(F)	5	8	12	7	6	22
Limit (K)	-1.5	-1	-0.5	0.5	1	1.5

Solutions

M = 1.233 $\quad$ $M.R = \frac{M}{D}$ $\quad$ $\text{Median}_{M.R \to K} = X_n$

$M.R = \frac{1.233}{34-32}$ $\quad$ $\text{Median}_{0.617 \to 0.5} = 38$

M.R = 0.617

5. Discussion

The target of this work has been accomplished as can be observed from the formula proving and solutions obtained in the two examples under the results. The solutions above shows no absolute or percentage error compared solutions that can be obtained by using other methods. This means that methods invented here are real or authentic. However, the methods invented here cannot solve problems for both grouped and ungrouped data with **non**-constant interval and **non**-constant difference among data sets $X_{1,}$ $X_{2,}$ $X_{3, \ldots}$ X_n respectively. In the first example of results the standard deviation 12.95 obtained was quite large. This indicates that the data is more spread out while in second example the standard deviation 1.36 was very small this means that data are less spread out. One of the advantages of this new method of solving these problems is that the three columns Dx, Df and DxDf contains terms that are a reflection of each other. This is an easy part for learners to fill in the table because one side is a reflection of the other. If the whole table in first example is compared carefully with the table of grouped data for old methods, Musonda table is simpler as shown below due to reflected terms.

Old method

Ages	f	x	fx	$(x - \bar{x})$	$(x - \bar{x})^2$	$f(x - \bar{x})^2$
0<x≤10	7	5	35	-23.2	538.24	3767.68
10<x≤20	22	15	330	-13.2	174.24	3833.68

20<x≤30	28	25	700	-3.2	10.24	286.72
30<x≤40	23	35	805	6.8	46.24	1063.52
40<x≤50	15	45	675	16.8	282.24	4233.6
50<x≤60	5	55	275	26.8	718.24	3591.2
Total	$\sum f$ =100		$\sum fx$ =2820			$\sum f(x-\bar{x})^2$ =16776

Musonda's method

Ages	Frequency (f)	X	D_x	D_f	D_xD_f	$fD_x{}^2$
$0< X \leq 10$	7	5	25	-1	-25	4375
$10< X \leq 20$	22	15	15	-3.5	-52.5	4950
$20< X \leq 30$	28	25	5	-2.5	-12.5	700
$30< X \leq 40$	23	35	5	-2.5	-12.5	575
$40< X \leq 50$	15	45	15	-3.5	-52.5	3375
$50< X \leq 60$	5	55	25	-1	-25	3125
Total	$\sum f$ =100				$\sum D_xD_f$ =-180	$\sum fD_x{}^2$ =17100

The columns $(x - \bar{x})$, $(x-\bar{x})^2$ *and* $f(x-\bar{x})^2$ in the method above have terms that are not similar and hence chances of learners or students making a mistake is higher than using Musonda's method. In order to prove the authenticity of my formulas/methods, the formulas were proven and variety problems were also solved using the old methods with mine and all solutions marched. This is strong evidence for further research on the use of difference in frequency (Df) and data (Dx) to solve different types of statistical problems other than ones discussed here. These different problems may include means of identifying Skewness, calculating coefficient of Skewness and so on.

6. Conclusion

In this study, I introduced a novel method for calculating mean, variance, standard deviation and mode. These methods streamline the computational process, reducing time complexity and computational resources required which can be particularly beneficial for large dataset. I demonstrated that these methods maintain or improve accuracy as compared to old methods.

The new methods are versatile and can be applied to various types of data distributions, making them broadly useful across different fields of study. The approach of these methods introduces new ideas in statistical calculations, potentially influencing future research and applications in data analysis. Other researchers and I now needs to invent other formulas/methods that can use the difference in frequency (Df) and data (Dx) to solve problems stated above that cannot be solved currently by the Musonda's method.

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Article 5

Effect of Integrating Social Media Technology (WhatsApp) and Hands-on-Activities in Teaching Chemistry Practical on Chemistry Students' Academic Performance

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Abstract

The study investigates the Effect of Integrating Social Media Technology (Whatsapp) and Hands-on- Activities in teaching Chemistry Practical on Chemistry Students' Academic Performance. Quasi-experimental research design was use in this study. The population of the study consists of 575 Chemistry students in Federal College of Education, Zaria. The sample size for the study involves 175 students. The instrument used for the research is Redox Titration Performance Test (RTPT) with reliability coefficient of 0.89 which was determined using Pearson Product Moment Correlation. One research question and one research hypothesis were analysed. The research question was answered using difference in the mean score of students in the experiment and control groups while the research hypothesis was analysed using t–test. Results revealed that students in the experimental group who were taught chemistry practical by Integrating Social Media Technology (Whatsapp) and Hands -on- Activities perform better than those in the control group who were taught same concept using Hands-on- Activities only. It was concluded that integrating social media technology (WhatsApp) and Hands-on- Activities enable chemistry students perform practical activities successfully from start to finish and gives the students an important sense of achievement. Recommendation was made which includes; the use of social media technology (WhatsApp) by students should be encouraged by providing them needed infrastructure such as steady power supply and internet facilities among others.

Key words: Social Media, Hands-On-Activities and Academic Performance.

1. Introduction

Science Education is seen as a prerequisite for scientific and technological development. It provides opportunities for students to acquire relevant functional knowledge and skills that are associated with scientific processes needed for advancement in science and technology. In the field of science education, students are encouraged to acquire and practice the scientific skills (David, 2018). Science education is concerned with finding answers to problems in a bid to understand and interpret natural phenomena. It is a tool use to inculcate self-discipline, scientific literacy and commitment in the minds of students. Science education is described as a process of combining knowledge of science with the study of education. It is the study of all science subjects such as Biology, Physics, Chemistry among others with various methods of teaching in other to impart scientific knowledge to individual learners (Olanrewaju, 2018).

Chemistry as a subject of study in science education. It deals with the composition, structure and properties of matter, the changes that matter undergoes, and the energy associated with those changes (Shirley, 2018). It is referred to as a central science subject because the basic knowledge of chemistry is essential to various branches of science including biology, physics, geology, medicine, engineering and technology (Anne, 2021). Chemistry, like other science subjects, trains the learners to acquire the science process skills of observing, experimenting, manipulation, classifying, communicating, inferring, hypothesizing, interacting with data and formulating models (Ojo, 2017). When Chemistry is taught using appropriate methods and resources it is said to be student cantered and effective.

The use of educational technology as well as the preparation and implementation of technology-based teaching are important factors in improving educational quality, particularly in teaching and learning chemistry. Technology has been used in the classroom since the nineteenth century. Initially devices such as the overhead projector were considered significant when compared to traditional technologies such as the chalkboard, the pencil and the ball point pen. More recently, rapid advances in computing have revolutionised how technology is implemented to enhance teaching and learning.

With the advent of the Internet and smart devices, access to information is now easier than ever before. For example, mobile phone technology has a 70% penetration and the majority of worldwide internet traffic is funnelled through smartphones (Boxer, 2018). The ever-present nature of technology in our daily lives facilitates rapid information access and permits alternative approaches to technology enhanced teaching to be adopted during (synchronous) and outside (asynchronous) class contact time (Pricahyo et al., 2018). Internet technologies are a growing phenomenon and their use is changing modes of communication and forms of sharing content among users.

Social networking applications are extremely popular among younger users and are widespread across the globe because they provide access to the community. These technologies are changing the concept of user interaction based on their application which makes them important to every individual. There is a daily increase in the number of users of such social networking forums, which predominantly provide interaction opportunities to individuals and groups to understand different worldviews and discuss evolving and differing thoughts. The scope of such networking applications and software is not limited to socializing alone but also has entered the sphere of education (Aktas & Can, 2019). Technology has the potential to enhance instruction, provide where and how learning occurs and the roles of students and educators in the instructional process. It is transforming procedures of instructional process by contributing components of strength to learning situations involving virtual environment. It is an effective and influential instrument for providing educational opportunities (Hussain, Suleman, Din & Shafique, 2017). Learning becomes effective and student centred when technology is incorporated into the curriculum.

Technology has brought sporadic learning opportunity that removes teaching and learning barriers in science. The interactive nature of teaching and learning of Chemistry offers a clear and enjoyable learning paradigm as in constructivists' learning (Neji & Ntibi, 2018). Effectiveness in teaching and learning could be accomplished depending on the availability of information on the subject matter, this includes E-learning materials in form of e-library, e-journals, virtual chemistry laboratory, e-textbook. Students at the higher institutions of learning can harness this information with the use of a well-equipped computer library, cell phones, laptops, tablets and many other electronic devices.

According to Neji and Ntibi (2018) learning is promoted when students are actively engaged in the learning process through activities and the use of material resources which encourages thinking and enables learners to link new information to old and acquire meaningful knowledge.

Technology improves performance by accessing online resources or embedded learning tools such as YouTube links (Aldalalah, 2021; Tsayang et al., 2020). Aktas and Aydin (2016) and Inaltekin (2020) found more learning retention in students instructed through the use of technology than in conventional classrooms. The interactive features of technology encourage and motivate students to participate and solve problems. For example, a Smart board could be touched with a pen or finger to draw a molecular structure while motivating students' participation. Such molecular structures can be sketched, dragged, cut, or copied from relevant sources and paste.

The rapid evolution of technology has profoundly transformed the world, making technology the preferred avenue for accessing vast realms of knowledge. The development of internet technology, in particular, has established it as the primary means of communication. Consequently, a significant portion of the global internet populace frequents social networking or blogging platforms, utilizing them as tools for communication and connection. Social networking sites (SNSs) represent online communities where internet users converge to interact with others who share common interests, spanning personal, professional, or academic spheres, as articulated by Amie-Ogan & Prosper (2020). The proliferation of social networking sites has turned the concept of a global village into a tangible reality, facilitating communication among billions of individuals worldwide. Distant communication via social networking platforms has yielded numerous benefits, enhancing connectivity and enabling interaction across vast distances (Aiyende and Omojola, 2021).

Social media are electronic instruments based on Internet technology with which parties can interact to promote collaboration and information sharing. Jamil, Ain, Batool, Saadat, Malik, Arshad, Nagra, Haider and Shameem and Latif (2020) define social media as a means of producing, sharing, and collaborating content online. Social media is a means of interaction that allows people to connect and share information. It refers to computer-mediated platforms that enable students to generate, share, and exchange information, ideas, images, and videos within virtual communities and educational settings. It influenced almost every aspect of life whether political, social, economic, and educational. It includes a diversity of applications such as Youtube, Telegram, Twitter, Facebook, WhatsApp, LinkedIn, virtual game and social worlds. According to Singh (2021) that social media platforms usage in schools motivates and fosters students to learn. Educational resources such as YouTube videos, readily available e-books, online notes, and learning through video calls are significant social media tools that inspire and encourage students to learn, thus enriching their educational growth.

Access to learning resources anywhere and anytime allows for deep learning (Abaido & El-Messiry, 2016). Smart Phones makes this possible as it allows for learning to occur anywhere and anytime. According to Vázquez-Can (2014), students use smartphones in varied ways including exchange of academic information outside the university physical walls. Outside the schools' walls, mobile devices are used for online interactions such as discussions and knowledge sharing. This is done through instant messaging, mobile social networks and Web based learning (Echeverría, Nussbaum, Calderón, Bravo & Infante, 2011).

WhatsApp is smartphone application that allows for instant message sending to either an individuals or groups. Pictures, Audio-Visual files attachment and websites links can be sent through it. It also allows for files sharing. WhatsApp was invented in 2009 by Jan Koum and Brian Acton and first became available on the market in 2010. WhatsApp use grew up rapidly: it gained over 350 million users, between 2010 and 2013. This is also evident by the use of WhatsApp in the healthcare industry (Kaliyadan, Ashique, Jagadeesan & Krishna, 2016). Among reasons that account for the popularity of WhatsApp, is its ability to allow for an almost fluent conversation, creating a sense of belongings, low cost, its accessibility and ease of use for communication purposes (Church & de Oliveira, 2013).

WhatsApp is said to have revolutionized social information exchange on all continents. It has even given rise to new expressions, such as Whatsapping in English or "Wasapear" in Spanish. Currently, the application is the most widely used for communication in real time or asynchronously. It is easy to use, has a limited data consumption cost and can be used to send audio and videos and share web addresses. It is updated and adds new functions in short periods of time to adapt to the needs of the users (Suarez-Lantaron, Deocano-Ruiz, Garcia-Perales & Castillo-Reche, 2022). Patient and Crispen (2011) are of the view that WhatsApp allows for academic information sharing through conversations between and among students using the application. Mistar and Embi (2016) opines that when WhatsApp is implemented in academics, students' motivation to learn rise, making performance increase. It also creates a more engaging environment (Abaido & El-Messiry, 2016). Odekeye, Fakokunde, Oladiji and Iwintolu (2023) found the use of WhatsApp had positive impact on students' academic performance as far as teaching and learning process is concern.

Abudullai (2013) describes hands-on activities as a method of teaching whereby students are engaged actively in class activities with the use of their hands and intellect under the guidance of the teacher. He is of the view that hands-on activities allow learner to demonstrate competency in materials and practical activities either by using his/her hands or other mechanical competencies. During Hands-on activities students have objects directly available for to manipulate their own self (Tile, 2013). Miller (2013) describes hands-on activities as consisting of different activities for the overall development of learner. Hands-on-activities is viewed as a teaching/learning method whereby tasks are carried out using hands to handle apparatus, equipment and reagents in the laboratory or work field which help learners to investigate, scientific problems in order to understand theories and principles of science (Adane & Adams, 2011).

The activities should be prepared from low cost materials which are available in the locality in this way the teacher may offer students a variety of active educational experiences structured according to the learning cycle. The cycle consists of an instructional sequence that include; engagement, exploration, development and extension. In the learning cycle the exercise begins with the engagement phase, whereby the teachers use real life or concrete activities, problems and questions to motivate students to learn about the topic and assess their prior knowledge. Students explore the content and phenomena by manipulating materials and start to address the presented questions (Miller,2013). Teaching and learning processes which involves hands-on activities is believed to help students in understanding theories and principles which are difficult or abstract (Ajayi, 2018). Iyamuremye, Nsabayezu, Ngendabanga and Hagenimana (2023) examined the effectiveness of hands-on practical activities in teaching and learning chemistry on academic performance in Rwanda and found that students are engaged and have a positive experience and perception on the use chemistry practical work with the aid of hands-on practical activities. A meta-analysis of the effectiveness of hands-on activities by Abah (2012) suggested that students may acquire more knowledge in short term when taught conventionally but are likely to retain knowledge longer when taught with hands-on activities teaching/learning method. Gallagher (2010) concluded in his study that hands-on activities is more effective than traditional instruction that it's result in better long-term retention than traditional methods of teaching.

1.1 Statement of the Problem

The integration of social media into classrooms has been a contentious issue for many years, with both parents and educators expressing concerns about its potential consequences. The popularity of social media is rapidly expanding worldwide, with increasing numbers of adults and teenagers joining platforms such as Facebook, MySpace, Skype, WhatsApp, and Twitter to connect with friends, family, and even strangers without considering its effect on students' academic performance. This study therefore investigates the Effect of Integrating Social Media Technology (Whatsapp) and Hands on Learning on Chemistry Students' Academic Performance in Chemistry Practical.

1.2 Objectives of the Study

The objective of this study is to determine the effect of integrating social media technology (Whatsapp) and Hands-on activity on Chemistry students' academic performance in Chemistry Practical.

1.3 Research Question

What is the effect of integrating social media technology (WhatsApp) and Hands-on Activities in Teaching Chemistry Practical on Chemistry Students' Academic Performance?

1.4 Research Hypothesis

The following hypothesis was tested at 0.05 level of significance:

There is no significant difference in the academic performance of Chemistry students taught chemistry Practical by integrating social media technology (WhatsApp) and Hands-on Activities and those taught using Hands-on Activities only.

2. Methodology

Quasi-experimental research design involving two groups experimental and control was use in this study. Students were grouped according to their course combinations. A WhatsApp group was created for students in the experimental group and 89 students were added. Video demonstration of each practical to be conducted was shared through whatsApp for students in the experimental group to watch, make comments and ask questions where there are difficulties or miss understanding and the researcher responds to each question ask before the Hands-on- laboratory activity was carried out. The two groups (Experimental and Control) meet on the Hands-on laboratory activity to receive the pre-lab lecture and carryout the Hands-on Lab practical together. This was done for six weeks with each week having different set-up for Redox titration exercise. After the treatment, the students' academic performance was tested using Redox Titration Performance Test (RTPT). Test was marked and scores were analysed using mean and t-test.

The population of the study consists 575 Chemistry students in Federal College of Education, Zaria. The sample size for the study involves 175 students. 89 students in experimental group and 86 students in the control group. An intact class was use and this was done according to course combinations. The sample size is in line with Andy field (2009) who recommended a minimum of 15 respondents as sample size for experimental research.

3. Results and Discussion of Findings

Research Question One: What is the effect of integrating social media technology (WhatsApp) and Hands-on Activities in Teaching Chemistry Practical on Chemistry Students' Academic Performance?

This research question was answered using difference in the mean scores of students in the experimental and control groups. Result shown in Table 1.

Table1. Mean difference in Academic Performance of Chemistry students taught Chemistry Practical using Social Media Technology (WhatsApp) and Hands-On Activities and those taught using Hands-On Activities only

Variable	Study groups	N	Mean	STD	Mean Difference
	Experimental	89	51.32	15.36	

Mean scores					10.744
	Control	86	40.58	12.60	

Table 1 revealed that difference exist in academic performance of Chemistry students taught Chemistry Practical using Social Media Technology (WhatsApp) and Hands-On-Activities and those taught using Hands-On Activities only. The academic performance of students in the experimental and control groups are 51.325 and 40.581 respectively, implying a mean difference of 10.744 in favor of students in the experimental groups. This shows that integrating social media technology (WhatsApp) and Hands-On Activities in teaching Chemistry Practical has a positive effect on Chemistry Students' Academic Performance.

Testing Null Hypothesis

The Null hypothesis which states that There is no significant difference in the academic performance of Chemistry students taught chemistry Practical by integrating social media technology (WhatsApp) and Hands-on Activities and those taught using Hands-on Activities only was Tested using T- test. Result shown in Table2.

Table 2: Independent t-test for academic performance of Chemistry students taught Chemistry Practical using social media technology (WhatsApp) and Hands-on Activities and those taught using Hands-on Activities only

Variable	Study groups	N	Mean	STD	Mean Difference	Df	T computed	T critical	P
Mean scores	Experimental	89	51.3258	15.36508	10.74445	**173**	5.048	**1.96**	**0.000**
	Control	86	40.5814	12.60295					

p≤0.05

Table 2 shows the calculated p-value for the t-test for academic performance as 0.00 which is lower than 0.05 level of significance set for the study. This shows that significant difference exists in the academic performance of Chemistry students taught chemistry practical using social media technology (WhatsApp) and Hands-on Activities and those taught using Hands-on Activities only in favour of students in the experimental group. Therefore the null hypothesis which state that; there is no significant difference in the academic performance of Chemistry students taught chemistry Practical using social media technology (WhatsApp) and Hands-on Activities those taught using Hands-on Activities only is hereby rejected

The findings in Table 2 is in line with that of Odekeye, Fakokunde, Oladiji and Iwintolu (2023) who found that the use of WhatsApp had positive impact on students' academic performance. It also agrees with Mistar and Embi (2016), who instigated that the use of WhatsApp in academics, motivates students to learn and raise their academic performance. Iyamuremye, Nsabayezu, Ngendabanga and Hagenimana (2023) examined the effectiveness of hands-on practical activities in teaching and learning chemistry on academic performance in Rwanda and found that students are engaged and have a positive experience and perception on the use chemistry practical work with the aid of hands-on practical activities. A meta-analysis of the effectiveness of hands-on activities by Abah (2012) suggested that students may acquire more knowledge in short term when taught conventionally but are likely to retain knowledge longer when taught with hands-on activities teaching/learning method. Gallagher (2010) concluded in his study that hands-on activities is more effective than traditional instruction that it's result in better long-term retention than traditional methods of teaching.

4. Conclusion

Based on the findings in from this study the following conclusions were made:

1. The use of social media technology (WhatsApp) has positive effect on Students' Academic Performance in Chemistry Practical.
2. Integrating social media technology (WhatsApp) and Hands-on- Activities enable chemistry students perform practical Chemistry successfully from start to finish and gives the students an important sense of achievement.

Recommendations

The researcher put forward the following recommendations

1. The use of social media technology (WhatsApp) by Students should be encouraged by providing them needed infrastructure such as steady power supply and internet facilities
2. School authorities should liaise with other educative web sites to partner with WhatsApp for academic achievement.

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Article 6

Facilitating Students' Learning Outcomes in Basic Science Using Innovative Integrated Inquiry -Based Science Teachers' Practice in Taraba State, Nigeria.

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Abstract

This study examined the Students' Learning Outcomes in Basic Science Using Innovative Integrated Inquiry -Based Science Teachers' Practice in Taraba State, Nigeria. Three specific objectives with corresponding research questions and two hypotheses guided the study. The study adopted a quasi-experimental research design of non-equivalent research design of non-equivalent group. Intact classes were assigned to both the experimental group (Integrated Inquiry-Based Teachers Practice Instructional Strategy) and control group (guided Inquiry Instructional Strategy) using multi stage sampling technique. The population for the study was 1,141 basic education students. The sample for this study is 292 Basic Education students comprising of 139 boys and 153 girls from six public secondary schools. Data for this study was generated using the instrument named Basic science Performance Test (BSPT), Kuder-Richardson (K-R20) formula was used to estimate the reliability index of 0.85 for the BSPT. Mean and standard deviation were used to answer all research questions. While, Analysis of Covariance (ANCOVA) was used to test the hypotheses at 0.05 level of significance. Based on the data collected and analyzed, there was significant difference in the mean academic performance score of students taught Basic Science using integrated-inquiry-based Science Teaching Strategy and those taught using guided inquiry instructional strategy, The study therefore, recommended among others that basic science teachers should be encourage to use Integrated Inquiry-based Science Teaching Strategy. In conclusion, it is evident from the finding of this study that the use of integrated inquiry-based science teachers practice could provide a good way for Basic Education students to learn Basic Science; since the strategy enhanced students' academic performance in Basic science.

Keywords: *Integrated Inquiry-based Science, Teaching, strategy, Students, and Academic Performance.*

1. Introduction

Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence; it is the observation, identification, description, experimental investigation and theoretical explanation of natural phenomenon. Science is a systematic investigation of nature with a view to understanding and harnessing them to serve human needs (Okoro, 2013). The importance of science has led scientist to strategizing on how to develop science and technology to earn national and international recognition. The world is becoming a global market with every nation struggling to control it through scientific investigation with capacity to attract global acceptances. The scientific development of a nation is dependent on the level of scientific knowledge of her citizenry (Abungwa, Okene & Wachanga, 2014). Therefore, science being the foundation for sustainable development is undeniably and unquestionably a key to national economic growth and prosperity. In the current information and technology age, when scientific information increases day by day, technological innovations advance rapidly, it is clearly seen that education in science plays a key role for the future of the society because the effects of science are seen overtly in every aspect of our lives. This could be one of the reasons science concepts is taught at the Primary School in the form of Basic Science.

Basic science is the science subject designed to expose learners to scientific and technological knowledge and skills that will assist them to make informed decisions, develop strategies and learn to contribute meaningfully in the contemporary society (Ellah & Achor, 2017). This implies that acquisition of adequate knowledge in the subject could equip the learner with what it takes to become useful to the society and also to be prepared for further studies in science thus fulfilling, the National goals of Education in Nigeria (FRN, 2014). On the same note, Ayodele (2016) submitted that Basic Science is the bedrock of future understanding of advanced studies in Science, Technology and Engineering. This shows that the concept if well-captured could prepare the learner for further studies in science at the secondary school level of Education as insinuated by Oludipe (2012). This submission implies that the subject is the foundation of science education in Nigeria

The subject introduces learners to the basic rudiments of science at primary Education level. The National Policy on Education defines Basic Science as the aspect of education which leads to acquisition of practical and applied basic scientific knowledge. The main reason for teaching Basic Science is to widen the knowledge of students in science which enables them to appreciate the unity among science subjects and apply what they have learnt to real life situation (Nwafor, 2016). This submission by Nwafor indicates the need for learners to excel in basic science.

Despite this importance of basic science to life, students perform poorly in Basic Science as documented in the Education Resource centre of Taraba State Ministry of Basic and Secondary Education report of BECE results for Basic Science and Technology (BST) from 2013-2022. Statistics of results revealed poor performance by students in Basic Science. From the analysis, it is clear that there is a trend of poor performance as performance was inconsistent and score per year range. There is no appreciable improvement in academic performance of students in Basic Science in BECE between the years 2013 – 2022.

The performance of students is below average and therefore calls for serious attention. The low academic performance could be as a result of the teaching strategy adopted by Basic Science teachers which probably failed in enabling the students to apply what they have been taught to real life situation, hence unable to appreciate the unity among science subjects because it was probably taught without adequate teacher feedback.
Feedback is defined as a process by which teachers and students provide response during instruction to organize the learning and teaching process in order to increase students' performance. Feedback could be viewed as a valid and vital part of blending teaching and assessment. There are four main components of feedback as a process of formative assessment. These are explaining learning objectives and success criteria, increasing the quality of marking/feedback/record keeping, using self and peer assessment and increasing the quality of inquiry/dialogue (William, 2011). For the components of teacher feedback to be realized,

Inquiry as submitted by Danjuma (2015) is an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and testing those discoveries in the search for new understanding. The term inquiry is used to invoke the idea of teaching science in the way it is actually practiced by scientists, that is, problem-solving through formulating and testing hypothesis Teachers use varieties of assessment activities and strategies in problem-solving to gain comprehensive insight into how much students learn via feedback integrated-inquiry-based as an instructional strategy in science practice. Feedback is a process by which teachers and students provide response during instruction to organize the learning and teaching process in order to increase students' performance. The types of inquiry-based learning as clearly outlined by Yoon, Joung and Kim (2012) are: Confirmation inquiry, structured inquiry, guided inquiry, open/true Inquiry and integrated inquiry-based strategy.

Warner and Myers (2014) submitted that Integrated inquiry-based science teaching is a student-centered pedagogical approach that leverages the interconnections across different areas of science and focuses on cultivating critical thinking and problem-solving skills in students through active investigations. Some key components and teacher practices include:

1. Feedback integrated inquiry- based practice: Effective use of feedback integrated inquiry-based practice involves the learners in teaching and learning processes. it is the process which teachers and students provide response during instruction to organize the learning process for attainment of stated objectives.

2. Integration across domains: The curriculum and learning activities incorporate linkages across domains like physical, life, earth sciences rather than teaching them separately. Students learn to apply concepts across disciplines.

3. Student-directed exploration: Learners are able to frame research questions, design experiments, collect observation data, analyze results and draw evidence-based conclusions with appropriate scaffolding. Activities develop lab, analytical and questioning abilities.

4. Hands-on investigations: Students conduct practical and interactive investigations through lab work, field studies, controlled tests, simulations etc. manipulating variables and witnessing concepts first-hand through repeated trials.

5. Critical analysis: Learners are taught to synthesize findings, critique methodologies, assess sources, argue using evidence, identify knowledge gaps and formulate further questions to continue inquiry. Develops analytical skills.

6. Collaborative work: Group discussions, team-based projects, interactive presentations and peer learning tasks enable perspective sharing and allow students to build on each other's ideas under teacher guidance.

The teacher plays a shaping role by planning appropriate sequences of problems, questions and investigations that connect concepts across domains, guide student inquiry using probes, promote evidence-based reasoning skills and collaborative work behaviours. Assessment includes project outcomes, portfolio submissions and concept application tasks. Integrated Inquiry-Based Strategy is a hybrid of two or more types of inquiry-based learning. Integrated-inquiry-based learning involves developing questions, making observations, doing research to find out what information is already recorded, developing methods for experiments, developing instruments for data collection, collecting, analyzing, and interpreting data, outlining possible explanations and creating predictions for future study. The teachers' role is that of modifying students' responses. Integrated inquiry-based instructional strategy addresses the context of basic science from multiple subject area.

Academic performance is defined as a measurable, observable and specific statement that clearly indicates what a student should know and be able to do as a result of learning experience. It consists of individual scores at any particular time obtained from either a teacher-made test or a standardized test. According to Spady (2016) academic performance are statements that describe significant and essential learning that learners have achieved, and can reliably demonstrate at the end of a programme. Spady notes that academic performance identifies what the learner will know and be able to do by the end of a programme. In Nigeria, at least a credit pass in Basic Science is the requirement for getting admission into secondary school to study Secondary School Science. However, this trend of poor students' performance in Basic Science has aborted the ambition of many students' studying science discipline programmes such as medicine, space science engineering, (ICT) among others.

In reference to gender, Nworgu, Ellah and Oparah (2019) opine that gender is a dimension of social organization which shapes how people interact with others and how people behave or act and think about themselves. Gender is the societal meaning assigned to male and female with a particular role that each should play. This is verifiable in relation to belief, interest and academic performance of students in this study because there is a general belief among Nigerians that male are superior to female in terms of physical, cognition, logical reasoning and academic achievement (Ellah, 2014). Furthermore, Garba (2019) found that gender has impact on science education. The author noted that boys appear to have a natural positive interest to technical and science subjects while girls show negative interest. However, there are mix results on the achievement of male and female in science. For instance, Egbo (2015) found that female students achieved better than male students in the science subjects. On the other hand, Liga and Emaikwu (2015) found no significant difference in science achievement between male and female students.

The poor performance of students in Basic Science is taken as a wake-up call to re-examine the methodologies in use, to prevent it from constituting a clog on the wheel of educational progress of Nigerian learners at the primary school level offering Basic Science. This is because a credit pass in Basic Science is required for admission into secondary school to learn science subjects that may enable them study Medicine, Pharmacy, Nursing and other Science related disciplines at the university level. It therefore follows that there is the need for science educator to check students' poor performance in basic science during basic education level, program at the primary education to avoid low enrolment into sciences at the secondary school education level. Therefore, there is an urgent need for an innovative teaching strategy such as feedback integrated-inquiry-based that could improve students' beliefs, interest and academic performance in Basic Science.

1.1 Purpose of the Study

The purpose of this study was to investigate the Students' Learning Outcomes in Basic Science Using Innovative Integrated Inquiry -Based Science Teachers' Practice in Taraba State, Nigeria. Specifically, the study sought to:

1. Find out the effect of integrated-inquiry-based science teaching strategy and guided inquiry instructional strategy on students' Academic Performance in Basic Science.
2. Ascertain the effect of integrated-inquiry-based science teacher and guided inquiry instructional strategy practice on male and female students' Academic Performance in Basic Science.

1.2 Research Questions

The study was guided by the following research questions:

- What is the effect of integrated-inquiry-based science teaching strategy and guided inquiry instructional strategy on students' Academic Performance in Basic Science?

- What is the effect of integrated-inquiry-based science teaching strategy and guided inquiry instructional strategy practice on male and female students' Academic Performance in Basic Science

Hypotheses

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

1. There is no significant difference in the mean academic performance score of students taught Basic Science using integrated-inquiry-based Science Teaching Strategy and those taught using guided inquiry instructional strategy.
2. There is no significant difference in the mean academic performance of male and female students taught Basic Science using integrated-inquiry-based Science Teaching Strategy and those taught using guided inquiry instructional strategy.

2. Materials and Methods

2.1 Research Design

The research design that was adopted for the study was quasi-experimental design of pretest, posters and non-equivalent groups

2.2 Area of Study

The study was conducted in Jalingo Education Zone of Taraba State, Nigeria.
Jalingo education zone is made up of three local governments namely; Ardo-kola local Government, Jalingo Local Government and Lau local Government.

2.3 Population of the Study

The population of the study consisted of all the 4,141 upper basic II Students from the 50 Public Secondary Schools in Jalingo education zone of Taraba State 2023/2024 academic session, Taraba State Ministry of Education, Post Primary School Management Board. The population of Upper Basic II Students which will consist of 2,338 males and 1,803 females' students

2.4 Sample and Sampling Technique

The sample of the study comprised of 292 Upper Basic Education Two students from Jalingo Education Zone. Which was made up of 139 male students and 153 female students randomly drawn from 6 intact classes which constituted the sample for the study? The multi-stage random sampling techniques were used in constituting the sample for the study.

2.5 Instruments for Data Collection

The instrument that was used for the study was adapted and organized by the researcher. The instrument that was use for the study to collect data was Basic Science Performance Test (BSPT).

2.6 Reliability of Instruments

In order to determine the internal reliability of the instruments, 40 copies of the instruments were pilot test at Bali Education Zone of Taraba state which will not be part of the schools for the main study. The instrument was administered at GDSS Bali, the data obtained was analyzed to establish the reliability index of BSPT. The reliability index obtained was 0.85 for BSPT using K-R formula 20. The index above reveals that the instrument was highly reliable for the study.

2.7 Method of Data Analysis

Means and Standard Deviation was employed to answer the research questions 1-2, while Analysis of Covariance (ANCOVA) was used to test the null hypotheses 1-2 at 0.05 level of significance.

3. Results

Research Question One.

What is the mean performance score of students taught basic science using integrated inquiry-based science teaching strategy what and those taught using guided inquiry instructional strategies? Data answering this question are contained in Table 1.

Table 1: Mean Performance Score of Students taught Basic Science using Integrated Inquiry-Based Science Practice and Guided Inquiry Instructional Strategies

Strategies		Pre BSPT	Post BSPT	Mean Gain
Integrated Inquiry-Based Science teaching strategy	Mean	8.72	21.84	13.12
	N	138	138	
	Std. Deviation	3.88	5.61	
Guided inquiry instructional strategy	Mean	8.40	17.16	8.76
	N	154	154	
	Std. Deviation	3.90	7.25	
Mean difference				4.36

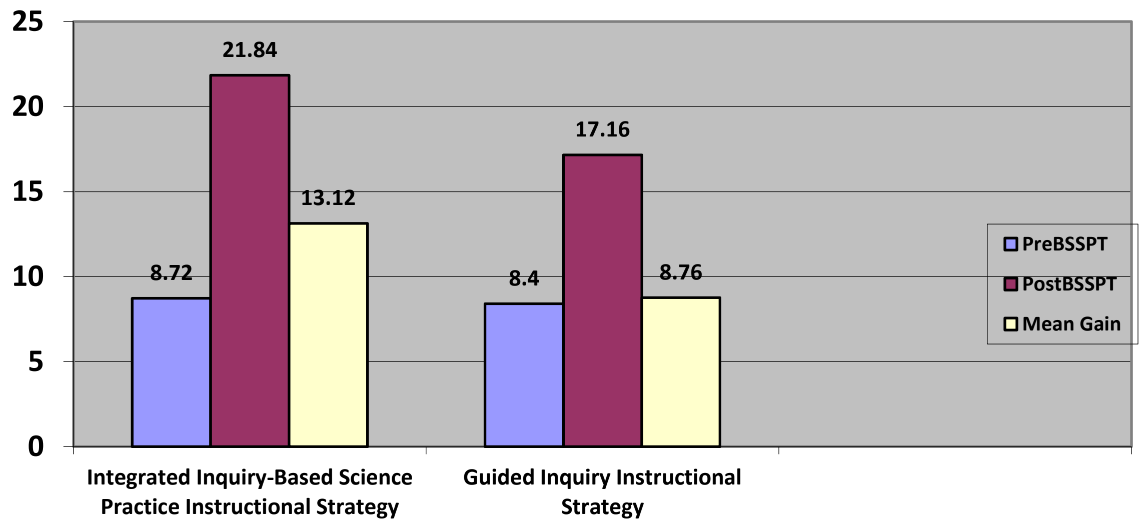

Figure 1

Pretest, Posttest Mean Gain in Performance Score of Students taught Basic Science using Integrated Inquiry-Based Science teaching strategy and Guided Inquiry Instructional Strategies.

Table 1 shows the mean performance score of students taught basic science using integrated inquiry-based science teaching strategy and guided inquiry instructional strategies. The table shows that 138 students were taught basic science using integrated inquiry-based science teaching strategy and 154 students were taught basic science using guided inquiry instructional strategy. The table reveals that the mean performance score of students taught basic science using integrated inquiry-based science practice instructional strategy is 8.72 with a standard deviation of 3.88 during pre-test and 21.84 with a standard deviation of 5.61 in posttest while the mean performance score of students taught basic science using guided inquiry instructional strategy is 8.40 with a standard deviation of 3.90 during pre-test and 17.16 with a standard deviation of 7.25 in posttest. The table further shows that the mean gain for integrated inquiry-based science practice instructional strategy is 13.12 and guided inquiry instructional strategy is 8.76. The difference in the mean performance score of students taught basic science using integrated inquiry-based science practice instructional strategy 4.36 in favour of students in integrated inquiry-based science practice class. The summary of the pretest, posttest mean performance score as well as the mean gain in the performance score of students in the strategies is as shown in Figure 1.

Research Question Two.

What is the mean performance score of male and female students taught basic science using integrated inquiry-based science practice? Data answering this question are contained in Table 2.

Table 2: Mean Performance Score of Male and Female Students taught Basic Science using Integrated Inquiry-Based Science teaching strategy

Gender		Pre BSPT	Post BSPT	Mean Gain
	Mean	9.01	22.29	13.28
Male	N	65	65	
	Std. Deviation	3.66	5.73	
	Mean	9.04	21.68	12.64
Female	N	73	73	
	Std. Deviation	3.73	5.49	
Mean difference				0.64

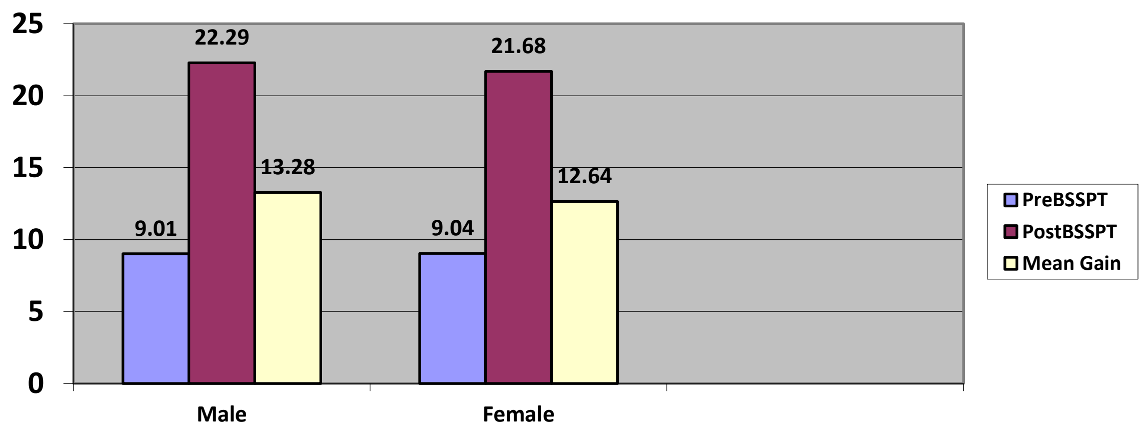

Figure 2

Pretest, Posttest Mean Gain in Performance Score of Male and Female Students taught Basic Science using Integrated Inquiry-Based Science teaching Strategy.

Table 2 shows the mean performance score of male and female students taught basic science using integrated inquiry-based science teaching Strategy. The table shows that 65 male students and 73 female students were taught basic science using integrated inquiry-based science practice instructional strategy. The table reveals that the mean performance score of male students taught basic science using integrated inquiry-based science practice is 9.01 with a standard deviation of 3.66 during pre-test and 22.29 with a standard deviation of 5.73 in posttest while the mean performance score of female students taught basic science using integrated inquiry-based science teaching strategy was 9.04 with a standard deviation of 3.73 during pre-test and 21.68 with a standard deviation of 5.49 in posttest. The table further shows that the mean gain for male students is 13.28 and females' student is 12.64. The difference in the mean performance score of male and female students taught basic science using integrated inquiry-based science practice 0.64 in favour of male students in integrated inquiry-based science practice class. The summary of the pretest, posttest mean performance score as well as the mean gain in the performance score of male and female students is as shown in Figure 2.

Hypothesis One

There is no significant difference in the mean academic performance score of students taught Basic Science using integrated-inquiry-based science teaching Strategy and those taught using guided inquiry instructional strategy. Data testing this hypothesis are contained in Table 3.

Table 3: ANCOVA of Performance of Students taught Basic Science using Integrated-Inquiry-Based Science teaching strategy and Guided Inquiry Instructional Strategy

Dependent Variable: postBSPT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1776.946[a]	2	888.473	21.081	.000	.127
Intercept	15691.284	1	15691.284	372.318	.000	.563
Performance	183.556	1	183.556	4.355	.038	.015
Strategies	1546.257	1	1546.257	36.689	.000	.113
Error	12179.859	289	42.145			
Total	123629.000	292				
Corrected Total	13956.805	291				

a. R Squared = .127 (Adjusted R Squared = .121)

Table 3 reveals that $F(1,289) = 36.689$; $p = 0.000 < 0.05$. Thus, the null hypothesis is rejected. This implies that there is significant difference in the mean academic performance score of students taught Basic Science using integrated-inquiry-based science teaching Strategy and those taught using guided inquiry instructional strategy. Thus, there is significant difference in the effect of integrated-inquiry-based science teaching Strategy and guided inquiry instructional strategy on mean academic performance score of students in Basic Science. The partial Eta square of 0.113 obtain for strategies means that only 11.3 percent of students' mean academic performance in Basic

Science can be attributed to the strategies employed.

Hypothesis Two

There is no significant difference in the mean academic performance of male and female students taught Basic Science using integrated-inquiry-based science teaching Strategy and those taught using guided inquiry instructional strategy. Data testing this hypothesis are contained in Table 4.

Table 4: ANCOVA of Performance of Male and Female Students taught Basic Science using Integrated-Inquiry-Based Science teaching Strategy

Dependent Variable: postBSPT

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	130.327[a]	2	65.163	2.119	.124	.032
Intercept	7260.363	1	7260.363	236.062	.000	.647
preBSPT	118.308	1	118.308	3.847	.052	.029
Gender	12.294	1	12.294	.400	.528	.003
Error	3967.552	135	30.756			
Total	67810.000	138				
Corrected Total	4097.879	137				

a. R Squared = .032 (Adjusted R Squared = .017)

Table 4 reveals that $F(1,135) = 0.400$; $p = 0.528 > 0.05$. Thus, the null hypothesis is not rejected. This implies that there is no significant difference in the mean academic performance of male and female students taught Basic Science using integrated-inquiry-based science teachers practice. Therefore, there is no significant difference in the effect of integrated-inquiry-based Science Teaching Strategy on mean academic performance scores of male and female students in Basic Science. The partial Eta square of 0.003 obtain for gender means that only 0.3 percent of students' academic performance in Basic Science can be attributed to gender.

4. Discussion

Finding revealed that the mean academic performance scores of students taught basic science using integrated inquiry-based teaching Strategy was higher than those taught using guided inquiry instructional strategy. There was significant difference in the mean academic performance score of students taught Basic Science using integrated-inquiry-based science teaching Strategy and those taught using guided inquiry instructional strategy. This implies that significant difference exists in the effect of integrated-inquiry-based Science Teaching Strategy and guided inquiry instructional strategy on the mean academic performance score of students in Basic Science. The finding agrees with Igoh and Danjuma (2021) that students under rubric self-assessment tool scored higher than those taught using a conventional method. The finding agrees with Danjuma Michael and Ndong (2021) that student taught basic science using assignment feedback perform and retained knowledge higher than those taught without assignment feedback indicating that assignment feedback improves student, performance and retention in basic science. The finding agrees with Bajon and Danjuma (2021) that there was significance difference in the achievement between teaching strategies and students in the mean gain achievement scores of students taught using laboratory teaching strategy and their counterpart taught using traditional teaching strategy. The finding agrees with Tekin and Mustu (2021) that the use of research-inquiry based strategies in science courses in research was thus found to have a positive impact on students' academic achievements and scientific process skills.

The finding agrees with Ojekwu and Oguleye (2020) that there was significant difference in science students' performance scores across the experimental and guided inquiry groups ($P<0.05$) in both cases, students taught with the Jigsaw strategy achieved greater improvement in their mean scores than those taught with the conventional lecture method. The finding agrees with Fatokon (2020) that students taught using mole concept using PBL strategy perform better than those taught using lecture method. The finding agrees with Ozan and Kincal (2018) that the experimental group in which the formative assessment practices were performed had a significantly higher academic achievement levels than the students did in the guided inquiry group. The finding agrees with Yakubu (2016) that there was a significant difference in performance between students taught climate change using Field-based Teaching Strategy and those taught using lecture method in favour of those taught using Field-based Teaching Strategy. The finding agrees with Ukoh and Saheed (2018) that there was a significant mean effect of treatment on students Achievement in Basic science concepts. The finding agrees with Agboola and Oloyede (2018) that students taught with the lecture-demonstration as well as project method performed better than those taught with inquiry method.

The use of integrated-inquiry-based science teaching Strategy in the present study engages students' curiosity in science, provides opportunities for students to use appropriate laboratory techniques to collect evidence, necessitates students to solve problems using logic and evidence, encourage students to conduct further study to develop more elaborate explanations, emphasize the importance of writing scientific explanations on the basis of evidence. The teacher in the integrated-inquiry-based science practice classroom environment constructs a community of practice like the scientists' world. This enables student to take action as scientists did, experiencing the process of knowing and the justification of knowledge. This may be responsible for the significant difference in the mean academic performance score of students taught Basic Science using integrated-inquiry-based Science Teaching Strategy and those taught using guided inquiry instructional strategy.

Finding revealed that the mean academic performance of male students taught basic science using integrated inquiry-based science teaching strategy and female student taught basic science using integrated inquiry-based science teaching strategy There was no significant difference in the mean academic performance of male and female students taught Basic Science using integrated-inquiry-based science teacher's practice. This implies that the use of integrated-inquiry-based Science Teaching Strategy is gender friendly with reference to the mean academic performance scores of male and female students in Basic Science. The finding agrees with Bajon and Danjuma (2021) that there was significance difference in the achievement between gender of students in the mean gain achievement scores of students taught using laboratory teaching strategy and their counterpart taught using traditional teaching strategy. The finding agrees with Fatokon (2020) that PBL improve the achievement of both male and female students equally. The finding agrees with Audu, Ajayi and Angura(2017) that no significant difference in the mean achievement scores between male and female students taught Basic Science and Technology using guided inquiry instructional strategy. The finding agrees with Ajayi (2017) that there was no significant difference between the mean achievement scores of male and female students taught stoichiometry using hands-on activities. The finding agrees with Efe and Khalil (2016) that there is no significant difference in the academic performance of both male and female students exposed to demonstration instruction in teaching chemistry.

The finding agrees with Yakubu (2016) that there was no significant difference in performance between male and female students in the experimental group which implies the teaching strategy is gender-friendly. The finding agrees with Ogbonne (2012) that there was no significant difference in the level of achievement and retention of male and female students in statistics due to the use of the Kumon teaching strategy. The finding agrees with Achor and Shikaan (2015) that gender have no significant effect in the acquisition of science process skills in the experimental group. However, the finding disagrees with Sylvanus and Eke (2017) that male chemistry students achieved higher than their female counterpart. The finding disagrees with Saka-Alikinla, Owodunni, and Babatunde (2016) that the mean score of boys taught Basic Electricity using guided inquiry instructional technique was higher than the mean score of girls taught using the same guided inquiry instructional technique in the academic achievement test. The finding disagrees with Efe (2015) that there was significant difference in the performance of male and female students in the two groups.

Gender differences do not permeate basic science class when integrated inquiry-based science practice was used. The present study found no significant difference in the mean academic performance of male and female students taught Basic Science using integrated-inquiry-based science teaching Strategy. This implies that the use of integrated-inquiry-based Science Teaching

Strategy is gender friendly with reference to the mean academic performance scores of male and female students in Basic Science. The teacher in integrated-inquiry-based science teaching strategy class adapts the science practice process to the knowledge and ability level of male and female students. The teacher starting process, promoting students' conversation, transition between small groups and classroom discussions, intervene to clear misconceptions or develop students' understanding of content material and utilized student experiences to create new content knowledge irrespective of gender. This may be responsible for the no significant difference found in the mean academic performance of male and female students taught Basic Science using integrated-inquiry-based science teacher's practice.

Finding revealed that the profile plot of the interaction effect of gender and instructional strategies on students' academic performance in Basic Science shows that the plots for male and female do not intersect although not parallel. There was no significant interaction effect of gender and instructional strategies on students' academic performance in basic science. This implies that the use male and female students' academic performance in basic science cancelled the interaction effect of integrated-inquiry-based Science Teaching Strategy and guided inquiry instructional strategy. The finding agrees with Audu, Ajayi and Angura (2017) that no significant interaction effect between strategies and gender on the mean retention scores of students in Basic Science and Technology.

5. Conclusion

It is evident from the findings of this study that the use of integrated inquiry-based science teaching strategy could provide a good way for Basic Education students to learn Basic Science. The strategy enhanced students' academic performance in Basic science across gender. If integrated inquired based instructional strategy proposed in this study is adopted in Basic science and science teaching and learning, it will improve the performance of students in skills, development. This will equip the students intellectually and lead to a remarkable breakthrough in science, Technology, Engineering and Mathematic (STEM) in our country and globally.

6. Recommendations

The implication of this study and the associated recommendations as it borders on Basic Education are as follows: -

1.Basic Science Teachers should be encouraged to use integrated inquiry-based science teaching Strategy.

2. Basic science teacher's trainees should be trained on the use of this instructional strategy which could improve academic performance of Basic Education student.

3. Curriculum planners and science teachers should be incorporate innovative, problem solving and activity based pedagogical strategies like inquiry based instructional strategy in all teacher education instructions.

4. Professional bodies like Science Teachers Association of Nigeria (STAN) in collaboration with the Nigeria Education Research and Development center (NERDC) and Federal Ministry of Education should organize seminars, workshops and symposia on the use of inquiry based instructional strategy for science teachers at the federal, State and Local Government levels. If this training is done on regular basis, the science teachers will be proficient in use of innovative instructional strategy like integrated inquiry instructional strategy.

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Article 7

Innovative Pedagogical Strategies in STEM Education: Effect of code-switching instructional strategy on the academic achievement and retention of students in basic science in Bauchi Metropolis, Bauchi State Nigeria

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Abstract

The study investigated the effect of code-switching instructional strategy on the academic achievement and retention of students in basic science in Bauchi Metropolis, Bauchi State, Nigeria. The study adopted quasi-experimental non-equivalent control group design. A sample size of one hundred and thirty-seven (137) students were drawn from two randomly selected schools in the metropolis. The study was guided by two research hypotheses. The experimental group received the treatment (code-switching between English and Hausa languages). The instrument for data collection was the Basic Science Achievement Test (BSAT) administered as pretest, post-test and post post-test. The BSAT consisted of 20 structured items (open-ended questions) on respiration and excretion, with a Cronbach alpha reliability coefficient of 0.75. Data were analysed using mean, standard deviation and t-test. The data was first tested for normality using the Shapiro-Wilk test. Independent sampled t-test results indicated that there was statistically significant difference between the two groups in favor of the experimental group on post-test achievement scores. Further analysis showed that there was statistically significant difference between the retention scores of students in the two groups in favor of the experimental group. These results indicated that code switching instructional strategy improved students' achievement and retention significantly. This study therefore recommends that code-switching instructional strategy be adopted by basic science teachers in order to foster students understanding and consequently their achievement.

Keywords: *Code-switching, Bilingual Instructional Strategy, Academic Achievement, Retention, Basic Science, Bauchi Metropolis*.

1. Introduction

The modern world is characterized by advancement in science and technology. This implies that for Nigeria to achieve her aims and objectives of economic, political and cultural development, there is need for qualitative science education in our educational institutions, especially in basic education that culminate into a solid education background. The clarion calls for reforms and innovations in the teaching and learning of science is aimed at improving the quality of Science Education in Nigeria. This suggests that there are issues in science Education which calls for improvement as no country of the world can grow without quality science education. This view is corroborated by Rull (2014) who posited that Science is valued by society because the application of scientific knowledge helps to satisfy many basic human needs and improve living standards.

However, there cannot be quality scientific literacy among the populace if adequate foundation is not being laid to teach science to younger ones. Basic education is the foundation of quality education. This is corroborated by Amadioha & Akor (2018) who stated that basic education is the foundational educational level. This may also by implication be seen and perceived as the most fundamental education that is given to people. They affirmed that basic education is the base-line education on which all other educational advancement depend. The basic education in this context is like the foundation of a building on which all other loads for the building come. This same foundational education from inference determines the stability of the entire educational building that anyone can ever have. This therefore explains the importance of Basic Science in junior secondary schools. The position of Basic Science as the bedrock for all science subjects in the secondary schools, and by extension, tertiary institutions, has led to its inclusion in the Nigeria's school curriculum.

To buttress the emphasis on science and technology education in the national policy on Education, Basic Science has been made mandatory as a subject for all Nigerian children at the basic education level. The Basic Science concepts are organized into themes and avoid duplication of contents and unnecessary repetition of topics in the different science disciplines, it therefore arouses curiosity and develops scientific interests and skills in students. This is to help children to develop reflective thinking and good habits which are needed for scientific method and successful future life (Agogo&Ode, 2011). Basic Science is aimed at enabling the child who is exposed to it to acquire the specific science process skills such as observing, organizing information acquired, generalizing on the basis of acquired information, predicting as a result of generalization and designing experiment to check predictions (FRN, 2013). Basic Science is also a subject which is trusted to grant the students general education and emphasizes the importance of observation for increased understanding of the environment.

The Basic Science curriculum is a broad field curriculum in which subject matter is integrated with the various science subject areas of Biology, Chemistry, Physics, Astronomy, Geology and Environmental Science, and synthesized to provide a holistic and unified nature of science (FRN, 2013). The broad based multi-disciplinary: industry-oriented strategy brings students into the centre of learning and succeeds in removing the general phobia around the study of science. The task before the basic science curriculum in two-folds, namely to provide a sound general education for all Nigerian children and to lay an adequate foundation for these children who would further their education in the core sciences subjects such as Biology. Basic Science is taught at the primary and junior secondary schools so as to catch the pupils' heart young. This is to help children to develop reflective thinking and good habits which are needed for scientific method and successful future life (Agogo & Ode, 2011). The Basic Science Curriculum inculcates the right values and norms of the society to foster development.

Despite the relative importance of science and technology to the country's quest for technological advancement, there is a continuous trend of poor implementation of the basic science curriculum due to inadequate competencies. Such incompetence as identified by Chima (2021) are inadequate laboratory, instructional materials, poor teaching method, etc. He posited that most basic science teachers use the conventional method of teaching which have been found to be deficient in enhancing learning and achieving the objectives of basic science Curriculum. Inquiry method is hardly used in teaching. Teachers rely mainly on conventional method of teaching due to lack of adequate equipment and materials for practical work and also as a result of the fact that most teachers do not know how to use the available equipment/materials for practical work. This is a very big challenge facing the implementation of Basic Science Curriculum where students are required to enquire, invent, predict and control events, Chima noted. Amos, Folasayo, and Oluwatoyin, (2015) questioned the teaching strategies used by teachers in facilitating teaching and learning and noted that teachers have difficulty in using appropriate instructional strategies in teaching in the classroom and this contribute to students' poor academic achievement. The recent 2019/2020 Basic Education Certificate Examination (BECE) where over eighth thousand five hundred and fifty-three (8553) candidates failed the exam (Musbahu, 2021) gives credence to this. This could be attributed to the poor performance to teaching strategies employed by teachers. This is also corroborated by Isa, Mammam, Badar & Bala (2020) who posited that the teaching strategies used by teachers determine the extent to which students perform in their academics

Hence, to help improve students' interest and academic performance in Basic Science, innovative strategies which provide students with hands-on learning experiences need to be employed to teach the subject effectively. Basic Science teachers need to employ methods that will enable students to learn better, retain more knowledge and apply what is learnt to real life situations. This is why

Carlos (2010) suggested that code switching may offer a promising opportunity in this respect. Fundamentally the term code switching is the use of more than one language in a sentence. It is the practice of alternating between two or more languages or varieties of languages in a conversation. Carlos (2010) defined code switching as the process of shifting from one linguistic code to another depending on the social context or conversational setting. It is the act of using learners' first language (L1) or learners' mother tongue, while teaching in the class where the language of instruction is not the learners' first language.

Code switching plays a facilitating role in helping learners and teachers engage in sharing knowledge and avoiding a situation where the teacher presents the subject matter in English to a passive learner (Mzamani, 2019). Code-switching has attracted considerable research attention over the past ten years. Code-switching refers to the use of more than one code or language in the course of a single speech event (Abu Hait, (2014)). In the educational setting, code-switching has been found to be useful for informational and interpersonal purposes of communication. Studies have shown that code-switching is used to bridge gaps in comprehension arising from the students' lack of proficiency in language and science classes (Promnath & Tayjasanant, 2016). In the Malaysian context, studies also showed that science and mathematics teachers code-switched to Bahasa Malaysia and even sought the help of the English teachers when they encountered difficulties in explaining concepts in English (Yahaya, 2019). Besides facilitating teaching of science, code-switching has also been used for interpersonal purposes of communication in the classroom. Code-switching is used in conveying humour, praise, encouragement, an ice-breaker and chastising in the classroom (Then, et al 2011).

Stromvig (2018) argued that code switching is an essential tool in the classroom for both teachers and learners, who use a second language as a medium of instruction as it allows both teachers and learners to negotiate meaning; it thus facilitates interaction between the teacher and learners and between the learners themselves. They argued that if African languages are used as media of instruction in science, it may eliminate the great barrier that exists between the privileged English classes and the ordinary people. Other studies such as Moore (2002) suggest that similar switches trigger divergent interactive treatments; therefore, code switching can help bridge the gap in the discourse. In essence, it could possibly be more effective in the teaching and learning of basic science and enhancing learners' academic achievement

Academic achievement is the performance outcomes that indicate the extent to which learners accomplish specific goals that are the focus of activities in the classroom. Students' achievement in Basic Science and Technology is a moderate predictor of quality science education, especially at the higher level such as in Biology, physics and chemistry as posited by Enemarie, et al (2019). Academic achievement is measured by teacher-made tests or by Standardized Tests. Educational or academic achievement is the specified level of attainment or proficiency in academic work as evaluated by the teacher (Chamundeswari & Franky, 2015). Academic achievement is how well learners have performed their cognitive tasks, that is, their capacity to demonstrate mastery on their offered subjects when compared to a pre-determined standard. The answers to this question can be obtained through a test or test results. Academic achievement is interesting; it is essential to consider when evaluating all teaching-learning activities, since poor academic achievement or performance is synonymous with academic failure. According to the Cambridge University Reporter (2003), academic achievement is frequently defined as the results of an examination. Academic achievement can be defined as learning that occurred in the past and can be quantified using tests, portfolios, and expert judgments. Although information pertaining to a descriptive assessment is usually translated into a grading system such as GPA or subject grade, while determining the success of students in a formal education, academic achievement is a didactic term used for evaluating the quantity and success of students' learning through research, reports, experiments, and rating using numerous factors or variables (Omotere, 2011).

Given the vital roles science education plays in the lives of every individual and the nation's quest to achieve development, it is important that science tutors/teachers device an all-encompassing strategy that will enhance science teaching and learning in the classroom, strategies that carries everyone in the classroom along, without prejudice to gender and also enhance retention in learners. When appropriate teaching strategies are employed, it plays significant influence on students' retention ability of learners. Udu et al. (2022) concluded that employing active learning instructional strategies in teaching science subjects can enhance students' knowledge retention. This underscores the effectiveness of engaging students in the learning process through interactive and participatory methods to promote better retention of information.

Retention in learners refers to the ability of students to remember and recall information over time. It encompasses the capacity to store knowledge acquired through learning experiences and retrieve it when needed. Various factors influence retention in learners, including instructional strategies, cognitive processes, and individual characteristics. The literature provides insights into how different approaches and techniques can impact students' retention of information across diverse educational contexts. One aspect that significantly influences retention is the presentation of information. Research suggests that learners are more likely to retain information in their working memory when texts and images are simultaneously presented (Mohafa et al., 2022). This indicates that the manner in which content is delivered can affect how well students remember and internalize the material. By using appropriate instructional strategies such as code-switching instructional strategy, teachers can enhance students' achievement and retention in basic science in junior secondary schools

1.1 Statement of the Problem

The teaching of Basic Science in junior secondary schools in Nigeria, particularly in Bauchi State has been with the use of outdated methods of instruction which makes it difficult for students' to effectively understand some basic science concepts. This has led to poor academic achievement and retention of students in both internal and external basic science examination, as basic Science BECE results from 2015- 2020 has shown that there is need for improvement. In view of the usefulness of basic science in all fields of science, the poor performance of students and lack of interest of students' in choosing science in senior secondary schools' level and higher institution is of significant concern to stakeholders in education particularly at this secondary school level. Dinah, (2013) stated that most of the time the poor achievement of students' and their interest in Basic Science can be attributed to many factors such as infrastructure and teaching method which means classes are congested and the teaching methods are not learners centered or appropriate to motivate learners. Therefore, this study sought to determine the effects of code-switching instructional strategy on JSS two basic science students' achievement and retention in Bauchi Metropolis, Bauchi State

1.2 Research Hypotheses

The study was guided by the following null Hypotheses which were tested at 0.05 level of significance;

(i). there is no significant difference between the mean achievement scores of students taught basic science using code-switching instructional strategy and those who were not taught with code-switching instructional strategy

(ii) There is no significant difference between the mean retention scores of students taught using code-switching instructional strategy and those who were not taught using code-switching instructional strategy

2. Methodology

2.1 Participants and Sampling Methods

This study employed simple random sampling techniques to select two junior secondary schools from all the junior secondary schools in Bauchi Metropolis. The selected schools were matched in terms of teacher qualifications, student demographics, school facilities, and academic performance, as determined by site visits and examination of national examination records. The study included two experienced teachers (holding bachelor's degrees with over five years of teaching experience) and a sample of 137 students, comprising 75 males and 62 females, with a mean age of 11.5 years (SD = 1.124). The control group consisted of 73 students, while the experimental group comprised 64 students. Intact classes were used so as not to disrupt normal academic settings of the schools used. A pre-test was administered to establish a baseline and ensure equivalence in academic achievement between the two groups.

2.2 Measures

This study collected data on academic achievement using a Basic Science Achievement Test (BSAT) administered as pre-test, post-test and Post-post-test design. The researchers developed the test instruments by adapting questions from basic science scheme of work. The tests consisted of 20 structured items (open-ended questions) on respiration and excretion, with a Cronbach alpha reliability coefficient of 0.75, indicating good internal consistency. Experts from the University of Abuja's Department of Science and Environmental Education and participating basic science teachers established content and face validity. The Basic Science Achievement test was reshuffled and used for the post-test and retention test. The study instrument was piloted on 53 students in a school which was not part of the schools used for the study to establish content validity. The main study employed a quasi-experimental design, using a non-equivalent control-group design, due to the challenges of random assignment. Both groups were pre-tested and post-tested for academic achievement and retention, with the experimental group receiving Code-switching instructional strategy (the use of English and Hausa languages interchangeably) while the control group received no treatment in addition to conventional teaching methods.

The students in the experimental group engaged in active learning methods, such as experiments, group discussions, inquiry learning, and collaborative learning, which were enhanced by Code-Switching instruction aligned with the lesson's learning objectives. The teacher also allowed the use of code switching during their discussion and asking questions. In contrast, the control group received the same active learning methods without Code-switching. To control for the Hawthorne effect, each teacher taught their respective classes in their own schools after they were trained by the researchers on how to implement the lessons designed for them. Code-switching instructional strategy was implemented through a structured approach, involving outlining learning outcomes, probing prior knowledge, eliciting learning processes, and consolidating understanding. After six weeks, both groups underwent post-testing and post pos-testing.

3. Data Analysis

The achievement test consisted of 20 multiple-choice questions, with answers scored based on Bloom's taxonomy levels. Scoring ranged from 0 (wrong) to 4 (excellent), with a total possible score of 80. Student scores were converted to percentages and used in t-tests to compare pre-test and post-test results between groups. The independent t-test determined significant differences between groups, while Cohen's d test measured effect size. Linear regression analysis was used to determine if the intervention, rather than student characteristics, drove changes in academic achievement, controlling for student variables to isolate the intervention's impact. Data were analysed using SPSS version 26.

4. Results

The results of the pre and post-tests on academic achievement were summarized and analyzed. The data was first tested for normality using the Shapiro-Wilk test, and then analyzed using a t-test to compare means. Additionally, linear regression analysis was conducted to further examine the relationships between variables, after confirming that the data met the normality assumption.

Table 1: Descriptive Statistics of Achievement Scores between the Experimental and Control Groups

Group	Pretest Mean	N	STD	Post-test Mean	N	STD
Experimental	33.47	64	5.67	55.76	64	4.34
Control	35.73	73	5.43	39.83	73	5.47

The descriptive data of the pre-test and post-test mean scores on academic achievement was analyzed and presented in the table above. The mean on the pre-test of the experimental group was 33.47 with standard deviation of 5.67 and the control group was 35.73 with standard deviation of 5.43, while the post-test mean scores of the experimental group was 55.76 with standard deviation of 4.3 and the post-test mean score of the control group was 39.83 with standard deviation of 5.47. The experimental group obtained a higher mean gain score than the control group

Table 2: Results of the Independent Sampled t-test of the pre and post test scores between groups and test of equality of means

	t	Df	*P*-Value	Mean Difference	Cohen's *d*
Pre-test	0.042	135	0.966	2.26	0.3
Post-test	15.93	135	0.000	15.93	2.3

A *t*-test of independent samples on the pre-test showed no significant difference between the control and experimental groups with $t = 0.066$, $p = 0.966$ with the lowest Cohen's *d* value of 0.3 The pre-test scores were not statistically different between the groups. The independent sampled test of the post-test between the groups showed significant changes between the group, ***t=15.93, p < 0.000*]**. Cohen's *d* test was calculated to find the effect size of the treatment in this study. The effect size of the treatment calculated using Cohen's *ds* formula was 2.3, which is a very large effect size of the treatment. The Cohen's *d* of 2.3 is a 85-90% nonoverlap of the test score distribution between the participating groups (Cohen, 1988). Which means the experimental group perform approximately 85-90% better than the control group

Hypothesis Two:

Table 3: Descriptive Statistics of Retention Scores between the Experimental and Control Groups

Group	Post-test	N	STD	Retention score	N	STD
	Mean			Mean		

Experimental	55.76	64	4.34	53.76	64	3.67
Control	39.83	73	5.47	28.53	73	8.34

The results in table three above indicated that the experimental group had a retention mean score of 53.76 with standard deviation of 3.67 while the control group had retention mean score of 28.53 with a standard deviation of 8.34. The difference between the post-test mean score and retention mean score of the experimental is 2 in favour of the post-test. Although there was slight reduction in the retention mean score compared to post-test mean score, it can be inferred that students in the experimental group retained about 90% of the knowledge gained in the post-test achievement mean score. This implies that code-switching instructional strategy is effective in enhancing the retention ability of students in basic science

Table 4: Results of the Independent Sampled t-test of retention scores between groups

	t	Df	*P*-Value	Mean Difference	Cohen's *d*
Post-test	15.93	135	0.000	15.93	2.3
Retention Test	13.93	135	0.000	25.23	3.5

The result in Table 4 shows that a t-score of 13.93 with associated probability value of 0.000 was obtained with respect to the difference in the mean retention scores of students` taught basic science using code-switching instructional strategy and those taught with lecture method. Since the associated probability (0.000) was less than 0.05 level of significance set as the criterion for taking a decision, the null hypothesis (HO2) was hereby not accepted. It was therefore concluded that there is a significant difference in the mean retention scores of students taught basic science using code-switching instructional strategy and those taught without using code-switching strategy.

5. Discussion and Conclusion

The study's primary purpose was to determine the effect of code-switching instructional strategy on the academic achievement and retention of students in basic science in Bauchi Metropolis, Bauchi State, Nigeria. An analysis of data on students' academic achievement and retention levels in basic science indicated that the levels of academic achievement was the same at the start of the study and on the pre-test.

The analysis of results showed that code switching instructional strategy can improve academic achievement and retention among learners. The data analysis conducted in this study has established that learners in the experimental groups have significant gains compared to learners in the control group on academic achievement. The Cohen's *d* test on the *t*-test showed a remarkably higher effect size of 2.3, depicting that the differences in the scores of the students between the groups could arise due to the treatment.

The study contributes one of the best possible ways or methods of intervention to elevate the academic achievement levels and retention level of students in basic science. This observation is in line with the findings by Carlos (2010) and Promnath, 2016 who noted the significance of code-switching instructional interventions on enhancing meaningful learning. Code-Switching-based learning improves students' understanding of content knowledge, impacting their academic achievement and retention ability. Hence, the study brings to light how the use of code-switching in basic science learning can impact academic achievement among learners and their overall learning. Student's performance in the experimental group after the treatment highlights the significance of using code-switching instruction in the classroom to engage learners' minds and efficiently stimulate them to be more receptive to new information.

The findings of this study are very significant to the education system of Nigeria as it aligns with the Policy of engaging learners in their mother tongue or language of the immediate environment at the basic education level. The study is also of significance to the world as it has shown how fundamental the use of code-switching strategy is in enhancing academic achievement and retention among basic science learners. Students' engagement, curiosity, interest, and academic achievement were raised throughout the study. They had the chance to see abstract concepts in basic science being portrayed very easily compared to how they are portrayed in basic science textbook.

5.1 Implication of the Study

Integrating code-switching interactive based teaching improved basic science students' academic achievement and retention in the experimental groups more than in the control group. The improvement of academic achievement and retention by the students in the experimental group explains how Code-switching based teaching positively impacts the cognitive and affective domain of motivation envisioned in the variables measured in this study. The results from the study suggest that Code-switching based teaching improved the learning. Thus, if teachers can explore and align code-switching to their teaching of basic science, learning can be easily done as abstract and complex concepts will be explained with language they are understand well hence more meaningful learning.

6. Recommendations of the Study

The study recommends that schools should encourage teachers in the use of code switching instructional strategy in teaching basic science so as to enhance students understanding of science at the basic level. This will students build strong foundation that will enhance the development of cognitive and affective domains in the learning process, as supported by the study results and cognitive affective theory of learning with constructivism.

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Article 8

Hands-on STEM Learning in Design and Technology: An Investigation of Practical Skills Development in the JETS Program in Zambia

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Abstract

This paper investigates the effectiveness of the Junior Engineers, Technicians, and Scientists (JETS) program in developing practical STEM skills in Design and Technology. Skills in JETS have played a significant role in transforming young minds by promoting hands-on activities and thereby fostering lifelong learning, in alignment with Sustainable Development Goal (SDG) 4, which ensures quality, inclusive education and promotes lifelong learning opportunities for all. However, there has been limited research on the impact of hands-on activities on learners' ability to apply STEM skills to real-world problems. This study involved seventy-seven (77) learners in the JETS program, aged 12-18, who participated in the 2023 national JETS fair. The research employed qualitative approaches. Data and methodology included descriptive statistics and thematic analysis of designs and products. The findings revealed that 90% of learners reported confidence in applying STEM skills to address sustainable development challenges, demonstrating the development of practical skills to design and make products that solve real-world problems. Such problems include those that relate to road paving as well as those that relate to solving challenges of transport with less or no carbon emissions. The JETS program is effective in fostering learner empowerment and preparing young minds to tackle global issues, highlighting the importance of hands-on STEM education. Integrating hands-on activities in STEM education, as done in the JETS program, is crucial for developing practical skills and promoting sustainable development.

Keywords: Design and Technology, lifelong learning, skills, JETS, STEM

1. Introduction

Hands-on activities actively engage learners, enabling them to produce products that solve real-life problems. These activities are also used by professionals to complete tasks efficiently, often collaboratively. This aligns with the African Union's aspirations for an inclusive and sustainably developing African continent (African Union, 2012). Hands-on learning provides learners with techniques, skills, and tools that enhance self-esteem, thereby contributing to ending poverty and reducing inequalities. Such skills create opportunities for young people to thrive and generate employment.

The inclusion of hands-on skills categories in the Junior Engineers, Technicians, and Scientists (JETS) program has fostered critical thinking among learners, helping to revolutionize them through the use of technology and innovation in problem-solving. The hands-on skills in the JETS categories include carpentry and joinery, bricklaying and plastering, landscaping and gardening, floor and wall tiling, welding, domestic electrical installations, food technology, fashion technology, and cosmetology (MoE, 2024). With the Sustainable Development Goals (SDGs) in place, these skills will help build resilient infrastructure through innovative ideas as well as provide creative expressions for individuals. It will also allow individuals to specialize and find niches that suit their interests in society. The creation of real products signified the importance practical skills play in the life of learners thereby promoting lifelong learning. It suffices to say that the attendance and participation in Science Technology Engineering and Mathematics (STEM) practical skills were also by females showing a significant interest in skills. Figure 1. shows attendance by gender in practical skills with only 2 females participating in civil and mechanical engineering representing 18% of the participants in the categories. In as much as the participants did well in practical skills, there is an imbalance in the participation by the different genders.

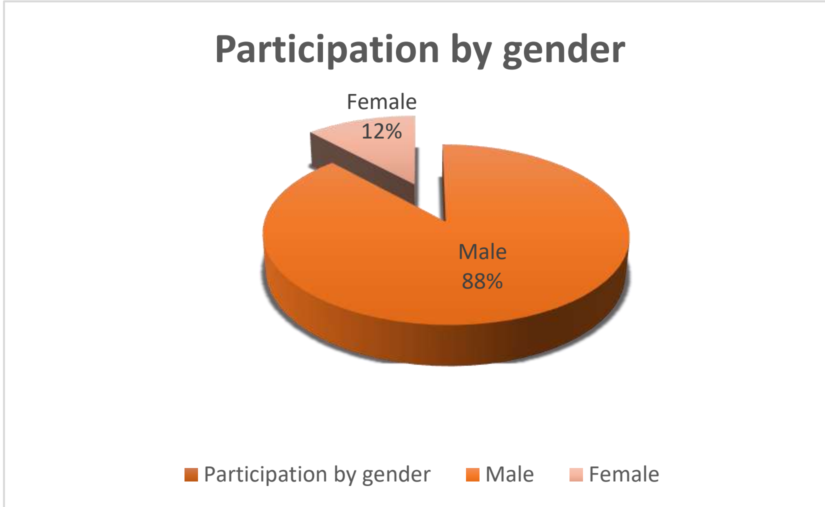

Figure 1 Participation by gender in practical skills

Figure 1. indicates participation by gender in practical skills. There is need for regions to encourage more girls (females) to participate in STEM practical skills to promote gender equality in creativity and innovativeness in learners.

1.1. Statement of the Problem

Since the introduction of STEM education in Zambia in 2019 and 2020, there has been ***limited research*** on the impact ***of hands-on activities on learners' ability*** to apply ***STEM skills*** to ***real-world problems.***

1.2. Objective of the Study

The objective of this study is to investigate the impact of hands-on activities on learners in the application of skills to solving real-world problems. The Ministry of Education through the National Science Centre incorporated skills in JETS in 2018 to place a premium on hands-on activities to ensure self-sustainability, as espoused by the 8th National Development Plan (8th NDP, p.16). (Republic of Zambia, 2022)

1.3. Study population

The research involved **77** participants from 11 regions that participated in the JETS fair in the various categories as shown in Figure 2.

Category	Number of participants
Mechanical Engineering	44
Civil Engineering	33
Total number of participants	**77**

Figure 2 Study population for the study

Mechanical Engineering incorporated; carpentry and joinery skills, panel beating & spray painting, welding as well as electrical installations with one participant in a respective skill area on one hand. On the other hand, civil engineering included bricklaying & plastering, paving (originally wall and floor tiling), and landscape and gardening. Other skill areas were fashion technology and Cosmetology. All these STEM Practical skills equips learners with self-sustaining skills in the long run create opportunities for entrepreneurial activities.

1.4. Research Question

1.4.1. What has been the impact of hands-on - activities for learners since their inclusion in JETS activities in 2018 in solving real-world problems?

2. Literature Review

2.1. Skills

To transform Africa into an integrated, prosperous, and peaceful continent, the need for skills becomes an integral aspect. Educating the human resource promotes and encourages production. In the latest trends, the job market seeks human resources that possess both soft skills and hard skills to achieve tangible results. Hard skills are teachable, while soft skills are personal traits that are more challenging to develop. In the Zambian context, every learner is encouraged to acquire and develop hands-on skills for sustainable development. These skills are gained through active engagement and practical learning, moving beyond traditional lectures. This resonates well with the theory by John Dewey who added that "Individuals learn best through direct experience and hands-on participation, rather than just through passive reception of information" (Dewey, 1916)

Hands-on skills offer numerous benefits, including financial empowerment, collaboration for problem-solving, and promoting sustainability in people's lives. According to a UNESCO report, "The Zambian Curriculum aims to produce holistic learners who manifest the appropriate values, skills, competencies, and knowledge to enable them to succeed in school and life." (UNESCO, 2018). This highlights the importance of inculcating values, skills, and competencies to promote 21st-century skills learning.

Skills training and teaching equip learners with positive social behavior to cope with negative pressures (Ministry of Education, 1996). These skills promote the health and well-being of learners through critical thinking and effective communication. Schools play a vital role in ensuring learners acquire skills for sustainable development thereby supporting STEM Education. The Tevet policy emphasizes offering training that fosters linkages between industry and vocational training for industrial experience and bridging the gap, (TEVET Policy, 1996)

Agenda 2063 emphasizes skills development as a driver of the continent's progress. One of its pillars is investing in Africa's people as its most precious resource. This investment will enable them to produce internationally accepted products that solve problems. To keep up with the latest trends, Artificial Intelligence (AI) plays a significant role in ensuring precision, accuracy, and efficiency in product realization. AI aids in designing, planning, cutting, optimizing materials, and finishing products with aesthetic values. It automates processes, supports intelligent designs, and maintains quality control. Skills and qualifications are strategic in the demographic bulge of the continent which sees them as the youth repository of the world, (CESA, 2016)).

2.2. Integration of hands-on activities in JETS Categories

Hands-on activities were integrated into the JETS STEM learning platform as a category in 2018 at the National fair held in the Copperbelt Province of Zambia at Kitwe College of Education. At that fair, skills that were introduced included domestic electrical installations, wall and floor tiling, landscaping and gardening, welding, fashion technology, food technology, and panel beating and spray painting (Ministry of Education, 2022). Learners' displays were impressive, with innovations that were ready to be utilized by the public. From then on, subsequent JETS competitions incorporated additional skill areas such as cosmetology and promoted hairdressing thereby opening a new dimension of creativity in the way to approach cosmetological issues.

The 2023 edition introduced a new dimension by segmenting the skill areas into two categories: Mechanical engineering and Civil engineering categories. The mechanical engineering category integrated skills such as electrical installations, panel beating and spray painting, carpentry and joinery, and welding. The civil engineering category incorporated skills in bricklaying and plastering, wall and floor tiling (paving), landscaping, and gardening. Situating the 8th National Development Plan (8NDP) in the vision 2030, the government premium on skills as enablers in the attainment of economic transformation and job creation, (8th National Development Plan, 2022).

Each category in the 2023 JETS had sub-themes to guide project interpretation. The 2023 sub-theme for the skills category was "***Sustainable and Marketing Designs***," which required participants to create sustainable designs that led to the development of the products. Participants designed, and produced products to solve real-life problems, promoting innovative and critical thinking. They organized and managed work, communicated effectively, demonstrated interpersonal skills, and solved real-world problems. Additionally, participants displayed skills in measuring, designing, planning, and producing tangible products for problem-solving. Integrating skills categories in JETS has significantly enhanced learners' performance and brought about innovations in product realization. This resonates well with the Vision 2023 for Zambia which states that “Learners will be expected to acquire three critical educational elements namely:

worthwhile skills, appropriate and applicable knowledge which will build up competencies", (GRZ, 2006)

3. Methodology

The research involved qualitative approaches. The data was collected through descriptive statistics and thematic analysis of designs and products.

4. Findings and discussions

Findings review that 90 % of the participants ***reported confidence*** in applying STEM skills to address sustainable development challenges, demonstrating the development of practical skills for designing and making products that solve real-world problems during the ***JETS*** National Fair and going forward. Some of the designs showcased by participants are as shown in figure 3 below.

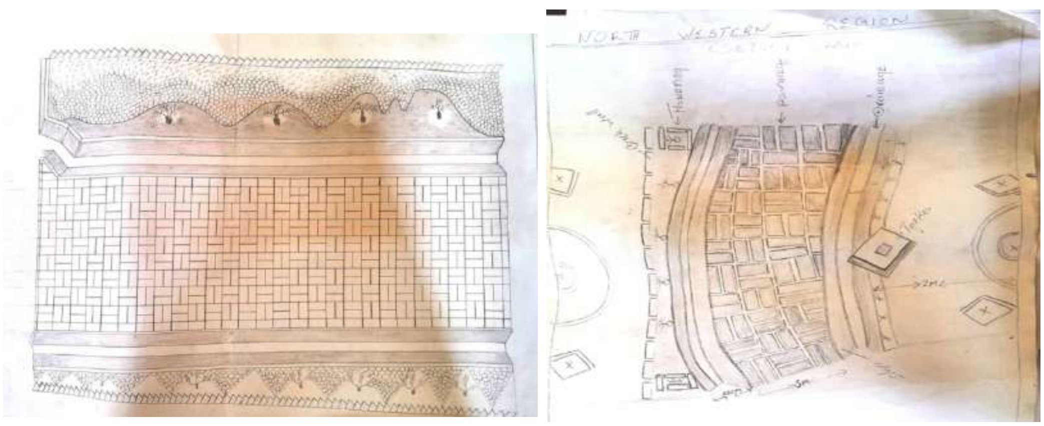

Figure 3 Designs for Civil Engineering Skills Competition

STEM practical skills provided a climax of practical activities during the national fair as participants created a hands-on atmosphere that motivated young learners to take part in creativity thereby responding to the vision 2030 that emphasizes "sustainable development, innovative and productive lifelong education for its citizens" (Republic of Zambia, 2006).

The integration of civil engineering in the JETS platform has had a transformative effect on young learners, offering numerous benefits and fostering a deep understanding of the field's importance. Participants gained practical experience in designing, planning, and constructing infrastructure projects such as roads and drainage systems, Learners developed essential skills in civil engineering, including problem-solving, project management, and teamwork. By engaging in civil engineering projects, students are better prepared for future careers in the field, contributing to the economy. The projects encouraged innovative thinking, as students had to find creative solutions to real-world engineering challenges. Civil engineering is a crucial field within the STEM disciplines, contributing significantly to the development and maintenance of infrastructure that supports modern society, (Scholar AI, 2024).

Learners were exposed to sustainable engineering practices, promoting environmental awareness and responsibility. Participants learned about efficient resource use and the importance of sustainability in construction projects. The projects emphasized the importance of safety in engineering, teaching students to design structures that protect public health and safety.

Learners gained insights into creating infrastructure that could withstand natural disasters, enhancing community resilience. The hands-on projects will have a direct positive impact on local communities as they will improve infrastructure in their communities and demonstrate the tangible benefits of civil engineering once they leave the formal school system.

The initiative fostered a sense of civic responsibility among participants, encouraging them to contribute to community development. The practical activities significantly increased student engagement and motivation, making learning more interactive and enjoyable. Students had the opportunity to apply theoretical knowledge to real-world scenarios, reinforcing their understanding and appreciation of civil engineering concepts. The fair allowed learners to handle significant responsibilities, fostering leadership skills and a sense of accountability. Working on civil engineering projects requires effective collaboration and communication, essential skills for any professional field.

Figure 4. shows designs that learners created when making electric cars in the mechanical engineering category. The category included carpentry & Joinery, Electrical installations, panel beating & spray painting as well as welding. The designs brought in tangible products even when learners could not complete them as desired.

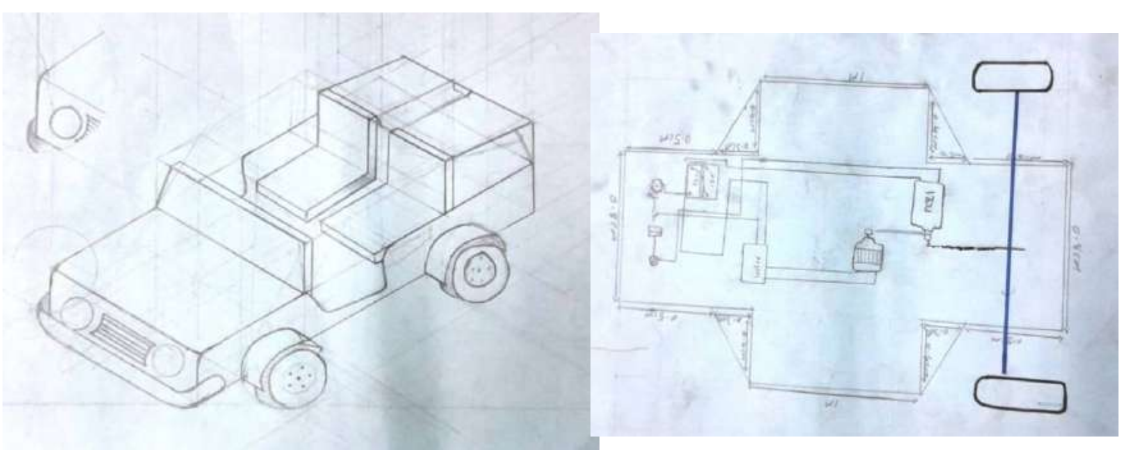

Figure 4 Designs in Mechanical Engineering Category

Mechanical engineering being a versatile field within STEM disciplines, drives innovation, supports economic growth, and improves the quality of life. It addresses critical challenges in energy, healthcare, transportation, and the environment, playing a vital role in shaping a sustainable and technologically advanced future (Scholar AI, 2024). Integrating mechanical engineering into the JETS platform offered significant benefits to learners, preparing them for future challenges and opportunities. Learners gained experience in designing and developing new products, fostering creativity and innovation. Learners were better prepared for careers in various industries, contributing to economic development as the skills acquired opened numerous job opportunities in design, production, maintenance, and research.

Practical activities in mechanical engineering significantly increased student engagement and motivation, making learning more interactive and enjoyable. Students applied theoretical knowledge to real-world scenarios, reinforcing their understanding and appreciation of mechanical engineering concepts. Handling significant responsibilities in projects fosters leadership skills and a sense of accountability. Working on mechanical engineering projects requires effective collaboration and communication, essential skills for any professional field. The 2023 JETS hands-on activities brought to the fore the preparedness of the learners to take up huge tasks in the nation for sustainable development as can be shown in Figure 5. below.

Region	**Standard frequency /practical skill**				
	Adherence to safety	**Ability to follow design and procedure**	**Use of tools and equipment**	**Ability to collaborate**	**Aesthetics**
	0 1 2 3 4 5	0 1 2 3 4 5	0 1 2 3 4 5	0 1 2 3 4 5	0 1 2 3 4 5
Region 1	4	4	4	5	4
Region 2	4	4	4	5	4
Region 3	4	4	4	5	4
Region 4	4	4	4	5	4

Region 5	4	4	4	5	4
Region 6	4	4	4	5	4
Region 7	4	4	4	5	4
Region 8	4	4	4	5	4
Region 9	4	4	4	5	4
Region 10	4	4	4	5	4
Region 11	4	4	4	5	4

Figure 5. ***Sample data collection sheet***

4.1. Impact of hands-on STEM learning in Design and Technology

Particularly in Design and Technology, hands-on STEM learning has significantly impacted education in Zambia. This approach emphasizes practical experience, encouraging students to apply theoretical knowledge to real-world problems. Hands-on activities increased student engagement by involving them directly in learning, making learning more interactive and enjoyable. Practical projects sparked curiosity and interest in STEM subjects, motivating students to explore further and deepen their understanding. Figure 6. below shows the application of skills developed to real-world situations.

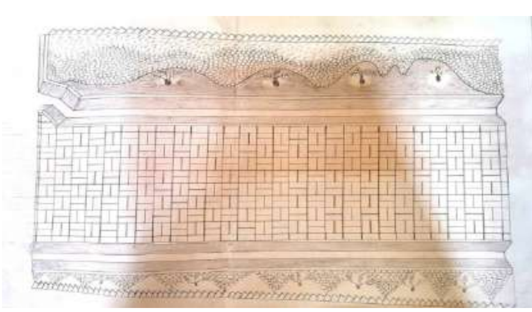

Figure 6. Designing and execution of Civil Engineering skills in road construction during the National JETS Fair

Students developed critical thinking skills while working through design challenges and technical problems. Hands-on projects encouraged innovative thinking, as students were tasked with finding creative solutions to real-world issues, (Francis, 2019). Students gain practical skills in design, engineering, and technology, which are essential for future STEM careers. Collaboration, communication, and project management skills were also developed through group projects and presentations. By applying theoretical concepts to practical tasks, students gained a deeper and more concrete understanding of STEM principles. Hands-on learning improved knowledge retention, as students were more likely to remember concepts they had actively engaged with. Students are better prepared for careers in STEM fields, having gained relevant skills and experience through hands-on projects, (https://www.academia.edu, 2024).

Enhanced STEM education contributes to the development of a skilled workforce, which can attract investment and create job opportunities. Students often work on projects that address local community needs, such as designing sustainable solutions or improving infrastructure. Hands-on STEM learning empowered students to take an active role in their communities, fostering a sense of responsibility and civic engagement. Exposure to design and technology projects can inspire students to pursue entrepreneurial ventures, leading to the creation of startups and innovative solutions as espoused in the revised 2023 Curriculum National Framework, (Ministry of Education , 2023) thereby enabling students to innovate and start businesses and contribute to economic growth and technological advancement in Zambia

Hands-on STEM learning in Design and Technology has profoundly impacted education and society in Zambia. By enhancing student engagement, improving problem-solving skills, and preparing students for STEM careers, this approach supports educational and economic development.

The practical experience gained through hands-on projects not only deepens students' understanding of STEM concepts but also empowers them to contribute to their communities and drive innovation. As a result, hands-on STEM learning is a critical component of Zambia's efforts to build a skilled workforce and achieve sustainable development.

Figure 7. Designing and making an automobile by participants in mechanical works during the National JETS Fair

5. Conclusion

The integration of civil engineering skills into the JETS platform has had a profound impact on young learners, providing them with valuable skills and knowledge that extend beyond the classroom. By addressing infrastructure needs, promoting economic growth, and ensuring environmental sustainability, civil engineering plays a pivotal role in shaping the future. The hands-on activities and real-world applications during the fair significantly demonstrated the potential of civil engineering to transform communities and empower the next generation of engineers. Mechanical engineering skills in the JETS platform also provide learners with valuable skills and knowledge, preparing them for future challenges and opportunities. By driving innovation, supporting economic growth, enhancing energy efficiency, and improving the quality of life, mechanical engineering significantly benefits learners and society. JETS is effective in fostering learner empowerment and preparing young minds to tackle global issues, highlighting the importance of hands-on activities in STEM Education. Integrating hands-on activities in STEM Education as done in the JETS program is crucial for developing practical skills and thereby promoting lifelong learning in learners which is a bedrock for national development.

6. Recommendations

Given this research, we can recommend the following:

6.1. STEM Hands-on activities in Design and Technology be promoted at institutional level
6.2. There is a need to ensure products that solve real-world situations are encouraged
6.3. JETS to encourage projects that react to current trends in society and global trends
6.4. STEM Hands-on activities be done more frequently to enhance quality

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Article 9

Project Based Learning and its Implementation in Physics at Ordinary level in Government Aided Secondary Schools in Ibanda Municipality

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Abstract

Experiences from curriculum design, development and assessment in STEM education foster practical teaching and learning. To our knowledge, school learning environment shows that Project based learning (pbl) has remained theoretical rather than practical in nature and that's a reason why some countries have remained backwards in terms of science and technology. This study therefore focused on examining the implementation of project-based learning in physics among ordinary level government aided secondary schools in Ibanda Municipality-Uganda. A descriptive research design was employed using both quantitative and qualitative approaches to allow comparison of responses. Both stratified, systematic, simple random and purposive sampling techniques were applied to select the 408 respondents. Data was collected using questionnaire and interview guide and was analyzed using descriptive statistics. The study revealed that Students are grouped and given supervisors for project learning; teaching timetable has a provision for project work; Students conduct research and engage in hands on activities during the project implementation. Noteworthy, students are unable to identify the critical project problems and present findings from project research through project dissemination. The study concluded that Students do not identify the critical project problem and they do not only present the product but also disseminate the product. The study recommends that learners should be allowed to think and identify societal problems, learners should be allowed to present their findings by disseminating their product through publications and teaching materials should be obtained from a learning environment.

1. Introduction

A teaching strategy known as project-based learning (PBL) involves having learners actively participate in projects that are both personal and practically relevant. PBL is a collaborative form of teaching and learning that involves elements of personal learning with active reflection and conscious engagement rather than passive experiences being involved (Kokotsaki, Menzies, & Wiggins, 2016).

The steps of the PBL model include: 1) student orientation to problems, 2) organizing students for learning, 3) guiding individual and group investigations, 4) developing and presenting work, and 5) analyzing and evaluating the problem-solving process (Akbar, Rahayu & Wanabuliandari 2022). In elaborating on constructivists' ideas, Arends (1998) states that constructivism believes in the personal generation of meaning by the learner. Constructivism has shortcomings, but it can allow a learner to reach better planes of knowledge and skill acquisition than would be possible otherwise (Jonassen, 1993).
Physics was the first program endorsed by the American Association of Physics Teachers, where 9th grade students take an introductory physics course, overwhelmingly underperformed (Qazi, 2019). Physics education in high schools of United States had registered low academic achievements because many states only required three science subjects that is physical science, chemistry, and biology (Dwight & Hugh 2017).

In Africa, academic achievement in physics in secondary schools across the continent dates back to the colonialism era of the 1900s, when science teaching was of a theoretical rather than a practical in nature, and physics as a subject, alongside other science subjects, was designed mainly as an introduction to scientific studies at advanced levels (Manià, Mabin, & Liebenberg, 2018).

In Uganda, the enrolment of Ugandans in secondary schools was low and on that small number, very few students chose to offer science subjects especially physics up to higher levels. Most of the students who offered sciences went to technical institutes and other tertiary institutions that were around by that time. The performance of science subjects has been poor ever since that time, however, there is a slight considerable improvement in performance and enrolment in the past 10 years (Sekiwu, Akena, & Rugambwa, 2022).

1.1 Problem Statement

Starting from the national assessment of the year 2024 at ordinary level, national grading will include project scores obtained from schools. Subject teacher will follow the observation checklist provided by UNEB. (Dan Odongo, the Executive Secretary of UNEB).

The government of Uganda has worked hard to build new and renovate existing science laboratories, supply physics textbooks, science kits, and resource materials, as well as in-service training for science teachers through SESEMAT, all in an effort to improve academic achievement in physics (Ministry of Education and Sports report, 2021). The Ibanda municipality's government-aided secondary schools continue to have low academic achievement in physics despite these efforts. According to the UCE scores for the 2018–2022 school year, physics was poorly performed, with the majority of students having failure grades (Ibanda Municipal Education Department report, 2022). Worth noting is that implementation of project-based learning is still lacking.

1.2 Objective of the Study

To examine the indicators of project-based learning (PBL) in physics at ordinary level in government aided secondary schools in Ibanda Municipality.

Hypothesis/question of the Study

H_0: Indicators of Project Based Learning in new curriculum have not been followed at Ordinary Level in Government Aided Secondary Schools in Ibanda Municipality.

Which indicators of Project Based Learning in Physics at Ordinary level in Government aided secondary schools in Ibanda Municipality have been followed in teaching and learning?

2. Methodology

2.1 Research Design

The study adopted descriptive research design which aims at systematically obtaining the information to describe a situation, or population.

2.2 Sample Size and Selection

The study targeted students, teachers, principal education officer, and municipal inspector of schools and head teachers. A sample population of 467 was selected from a study population of 578 participants with the response rate of 408. The sample population was determined using Krejcie & Morgan 1970.

2.3 Sampling Procedures/Techniques

Systematic sampling is a sampling technique where a list of elements in the population is randomly arranged either in alphabetical order or numerical order digits (Ken Black, 2004). It was used to select students in single sex schools that is; Ibanda ss and Kibubura girls' ss.

Stratified sampling is applied when a researcher wishes to ensure that particular categories in the population are represented in the same proportion as in the population. Such sub-groups may be about age, gender, class levels and religion. This design was used to reach students in mixed schools because of their nature of different sexes.

Simple random sampling is used to select a given small sample from a certain population randomly and it was used to reach physics teachers. And purposive sampling techniques was used to Principal education officer (PEO), Municipal Inspector of schools (MIS) and head teachers. This is because they serve as the Ministry of Education's representatives and are tasked with assessing all of the school's activities.

2.4 Data Collection Tools

Onen and Oso (2008) asserts that questionnaires are items or tools used to collect information over a short period. Self-administered questionnaires were widely used for collecting quantitative research data and interview guide checklist were used to collect qualitative data. Section A is bio demographic data about gender of the respondent and section B is a Likert scale ranging from strongly agree (5), agree (4), undecided (3), disagree (2) and strongly disagree (1).

2.5 Data Management

Quantitatively was analyzed using descriptive and inferential statistics to derive relevant descriptive statistics (Frequencies, means and percentages) which was additionally analyzed in order to attain relevant conclusions. Qualitative data that was collected using interview guide was analyzed using content analysis of NVIVO software which was done by reading through each transcript carefully to identify and eliminate bias; the transcripts were interpreted by labelling relevant words, phrases, sentences, or sections with codes.

3. Research Findings

This chapter presents the analysis and interpretations of the study findings arising from the data collected from the respondents' using questionnaires and interview checklist. It presents the analysis of the study findings in relation to indicators of project-based learning.

Table of Indicators of project-based learning in physics

Statement	SD	D	NS	A	SA	M
Students are grouped and given supervisors for project learning	65 (15.8%)	71 (17.2%)	13 (3.2%)	121 (29.4%)	142 (34.4%)	3.42
Class timetable has a provision for project work	58 (14.1%)	67 (16.3%)	21 (5.1%)	129 (31.3%)	137 (33.2%)	4.22
Student identify the critical project problem	148 (35.9%)	133 (32.3%)	28 (6.8%)	56 (13.6%)	47 (11.4%)	1.84
Students conduct research and hands on during the assessments	48 (11.7%)	33 (8%)	18 (4.4%)	155 (37.6%)	160 (38.8%)	4.62
Students present results from projects	165 (40%)	144 (34.9%)	11 (2.7%)	53 (12.9%)	39 (9.5%)	1.91

Source: Primary data (2023)

The results in the above table show that 65 (15.8%) strongly disagreed, 71 (17.2%) disagreed, 13 (3.2%) were undecided, 121 (29.4%) agreed and 142 (34.4%) strongly agreed that students are grouped and given supervisors for project learning with the mean of 3.42.

With regards to Key Informant F pointed out that;

In Project Based Learning, small, temporary groups of two to four students work together for brief projects in a class, to answer questions or respond to prompts posed by the teachers. For example, in this school, physics teachers always group students to undertake some activities such as bulb wiring, mechanical projects, making projects and other related projects that need demonstration.

It was also established that 58 (14.1%) strongly disagreed, 67 (16.3%) disagreed, 21 (5.1%) were neutral, 129 (31.3%) agreed and 137 (33.2%) strongly agreed that class teaching timetable has a provision for project work with the mean of 4.22. Basing on Key Informant B, has this to say;

Schools also have timetables for every subject/project for example the timetable places students at the proper time and in the proper manner. It prevents wastage of time and energy for both students and teacher.

The results in Table 1 show that 148 (35.9%) strongly disagreed, 133 (32.3%) disagreed, 28 (6.8%) were neutral, 56 (13.6%) agreed and 47 (11.4%) strongly agreed that student identify the critical project problem. The mean of 1.84 implies that the majority of the respondents disagreed with the statement. However, according to Key informant A claimed that;

Certain projects require specific skillsets in every group. I give students a survey a week ahead of time and ask them to identify their project according to the existing problem. Then I group them by skillset before we launch the project, balancing achievement level and skills. This is a great opportunity to honor students' skills that fall outside of the normal range of what we measure in schools, building self-confidence in them.

It was noted that 48 (11.7%) strongly disagreed, 33 (8%) disagreed, 18 (4.4%) were neutral, 155 (37.6%) agreed and 160 (38.8%) strongly agreed that students conduct research and hands on during the assessments. The mean of 4.62 implies that the majority of the respondents agreed with the statement.

It was noted that 48 (11.7%) strongly disagreed, 33 (8%) disagreed, 18 (4.4%) were neutral, 155 (37.6%) agreed and 160 (38.8%) strongly agreed that students conduct research and hands on during the assessments. The mean of 4.62 implies that the majority of the respondents agreed with the statement.

The results in Table 1 shows that 165 (40%) strongly disagreed, 144 (34.9%) disagreed, 11 (2.7%) were neutral, 53 (12.9%) agreed and 39 (9.5%) strongly agreed that students present results from projects. The mean of 1.91 shows that the majority of the respondents disagreed with the statement. According to key informant N pointed out that;

Students hardly give feedback to their supervisors. They like the ability to get immediate feedback, see their marks in the note board, and return to view the assessment later. The online method eliminates some of the potential problems of the pen-and-paper method for students: failure to obtain the paper assessment, failing to submit responses, failure to receive feedback on the responses and the teacher's failure to record the grade affects their performance especially in physics subject.

4. Discussion

The study aimed at examining the relationship between project-based learning and academic achievement in physics among ordinary level students in government aided secondary schools in Ibanda Municipality. This chapter, presents summary of discussion, conclusion and recommendations.

The study revealed that majority of the respondents agreed that Students are grouped and given supervisors for project learning; class timetable has a provision for project work; Students conduct research and hands on during the assessments. However, it was disagreed that students identify the critical project problem and students present results from projects.

The results are in line with Aminah, Fauzan and Fauziddin (2021) who revealed that it is necessary to educate pre-service teachers in approaches stressing the importance of the own activity of students. Project-based physics learning where learners make projects either individually or in groups seems to be one of the most effective methods for teaching physics science for understanding. It is necessary to provide in-service teachers instruction (seminars) and prepare sample projects with proposals on how to develop, run and evaluate interdisciplinary projects.

The findings are line with Muhammad (2022) who discovered that project-based learning (PBL) and team cohesion increased favorably on both the efficacy and engagement of students' learning. Flipped learning, on the other hand, had diminished positive effects on engagement and increased positive effects on student learning effectiveness.

The results are also in agreement with Wakumire, Nkundabakura, and Mollel (2022) who revealed a significant difference in the average scores of students' attitudes towards physics in favor of the experimental group. Therefore, the study recommends that science educators adopt PBL to improve students' attitudes. Much as the above study was done in Mbale, this study was conducted in Ibanda Municipality.

The results in line with Watt et al. (2019) who suggest that targeting a well-defined profile of students is more effective compared with targeting each individual in a classroom, since feedback can be easily individualized and instructional approaches are flexibly adapted to cater for a group of similar students rather than each individual. However, little work has been devoted to the person-centered approach by motivational researchers (Chittum & Jones, 2017; Vansteenkiste et al., 2009), especially in developing countries. Equally, research investigating the relationship between secondary school students' motivation and cognitive learning strategies during Physics learning in third world countries is very scarce.

The results are in line with Makkonen, Lavonen and Tirri (2023) who noted that students with an interest in a subject like physics are likely to be more motivated to manage their own learning and develop the requisite skills to become effective learners of Physics. Hence, interest in physics is relevant when considering the development of effective learning strategies for physics. In contrast, anxiety about learning physics can act as a barrier to effective learning. Students who feel anxious about their ability to cope in physics learning situations may avoid them and thus lose important career and life opportunities. Godpower-Echie and Ihenko (2017) opined that physics teachers should try to identify a teaching approach, method that can motivate or arouse students' interest. Interest is, generally, student attention, greater concentration, pleasant feelings, and increased motivation towards learning a concept (Afjar & Syukri, 2020).

The results are in agreement with Liliana, Raharjo, Jauhari and Sulisworo (2020) who noted that in the development of students' academic achievements, teachers display behaviors aimed at enabling students to grasp the subject of the lesson and reinforcing it with exercises, applying the correct assessment methods, using time efficiently, keeping students active in class, and enabling them to generate ideas. In efficient schools, teachers behave in a planned and disciplined way, target the academic success of the school and students, have sufficient knowledge in their field, consolidate students' positive behaviors, move on to the next stage for education to be provided in full, work in cooperation with students, and provide students with suitable feedback (Roberts & Webster, 2022).

The results are in agreement with Cheah (2021) who stated that efficient teachers' preparation of the classroom for teaching, and setting and imposing the class rules together with the students, enables retention of learning and allows students to display learning behaviors. An effective teacher trusts students and accepts them as they are, gives priority to students' achievements, appreciates them, stimulates interest towards the lesson in students, rewards them, prepares the classroom for education, is tolerant and flexible, makes the right decisions, and accepts and respects individual differences (Tanak, 2020). Teachers who are successful in their profession are patient and controlled, respect differences, are open to development and criticism, stimulate students, display role model behaviors, establish discipline in class, have leadership characteristics, encourage and support students, are affectionate, witty and sincere, find solutions to problems, monitor homework and facilitate learning (Ozcan, 2021). When the characteristics of an effective teacher are examined, it is seen that when a teacher has these qualities, academic success can be enabled in the student.

5. Conclusion

The study concluded that students are grouped and given supervisors for project learning supervisors are responsible for guiding students in the given specified time and awards scores to students. Class timetable has a provision for project work; Students conduct research and hands on during the assessments. However, it was disagreed that students identify the critical project problem and students present results from projects. Thus, students should perform projects basing on the problems affecting the society in order for school education to be meaningful. Therefore, the mean of 4.62 concluded that the majority of the respondents agreed with the statement that students do research and hands on projects that solve their daily challenges in the society.

6. Recommendations

The study recommends that students should perform projects basing on the problems affecting the society in order for school education to be meaningful. The creativity of a learner should be observed basing on the domains of Taxonomy.

The study recommends that evaluation in the project-based learning should be authentic. For instance, students may be required to submit written assignments, do observations, presentations and be involved in discussions. The self-evaluation tools can be helpful at the beginning to tell students what is expected from them. During the project supervision, the process could be taken into consideration more for the evaluation.

The teaching materials which are prepared should be based on the learning method and should be obtained from a learning environment, students develop better performance skills in STEM teaching and learning, and have more increased self-efficiency beliefs as compared with students instructed by using the traditional method.

The study recommends that students should identify projects basing on the problems existing in the society. This helps the school education to be meaningful in the society. Every phase made by a learner should be presented to the supervisor/teacher for analysis and exhibition time be set such that every student defends the product made in a particular time. The study also recommends that enough resources in form of scholastic materials should be provided so as to promote project-based learning and learner's academic achievement in physics at Ordinary level in government aided secondary schools especially in Ibanda Municipality.

The study recommends that schools should train teachers in continuous professional development (CPD) on how to improve the teaching of lower curriculum, setting activity of integration, setting and scoring continuous assessment items and how to score them, and assessment of end of year.

Schools should set exhibitions where learners present their findings in form of projects and explain the methodology. This improves on the communication skills, communication and critical thinking.

Head teachers should be trained on how to supervise teachers handling new curriculum. Some teachers take the advantage of ignorance of head teachers and financially exploit schools**.**

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Article 10

Roles of Emerging Technologies in Enhancing Mathematics Education

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Abstract

The article explores role of emerging technologies in enhancing mathematics education. The integration of emerging technologies into mathematics education has changed the traditional teaching and learning methodologies, providing innovative tools and approaches that enhance students' understanding and engagement. This paper explained the role of these technologies, including artificial intelligence (AI), virtual reality (VR), and adaptive learning platforms, in transforming mathematics education. AI-driven systems offer personalized learning experiences by adapting to individual student needs, thereby improving learning outcomes and retention rates. VR environments create immersive, interactive scenarios that allow students to visualize complex mathematical concepts in three dimensions, fostering deeper comprehension. Additionally, adaptive learning platforms provide real-time feedback and assessments, enabling educators to tailor instruction more effectively. The application of these technologies has shown significant impact on student motivation and achievement, as well as facilitating differentiated instruction and collaborative learning. Through a comprehensive review of recent studies and practical implementations, this paper also highlights the potentials of emerging technologies to address traditional challenges in mathematics education and to prepare students for future academic and career success. The findings suggest that leveraging these advanced tools can lead to more engaging, efficient, and equitable educational experiences, ultimately transforming the landscape of mathematics education.

Key Words: Role, Emerging, Technologies, Enhancing and Mathematics Education.

1. Introduction

Mathematics education is undergoing a transformative shift due to the integration of emerging technologies. These technologies have reshaped how mathematical concepts are taught, learned, and applied, offering new opportunities to enhance student's engagement, understanding, and achievement. In both developed and developing countries, including Nigeria, the adoption of digital tools and platforms is revolutionizing classroom dynamics, fostering a more interactive and personalized learning environment. This article explores the various roles that emerging technologies play in enhancing mathematics education, with an emphasis on their application in both global and Nigerian contexts.

1.1 Overview of Emerging Technologies in Mathematics Education

A. Definition and Scope of Emerging Technologies

Emerging technologies refer to the innovative tools, methodologies and systems that are in the early stages of development and adoption, with the potential to significantly transform industries, education, and societal practices Eze, and Chinedu-Eze, 2018). These include advancements such as artificial intelligence, robotics, blockchain, and data analytics, which can revolutionize education by providing more interactive and adaptive learning environment

Emerging technologies refer to innovative tools and platforms that have the potential to significantly impact educational practices (Hsu, Ching, & Grabowski, 2014). In another way Cascio and Mitchell, (2016) define emerging technologies as a new and rapidly evolving tools, techniques, and platforms that have the potential to drive significant changes in industries and education. They include innovations such as artificial intelligence, blockchain, and the internet of things, which promise to reshape traditional methods of teaching and learning by offering greater customization, interactivity, and efficiency. It also includes virtual and augmented reality (VR/AR), machine learning, adaptive learning systems, and collaborative online platforms. In mathematics education, these technologies facilitate interactive learning, real-time feedback, and personalized instruction, thereby transforming traditional teaching methods (OECD, 2019).

B. Global Adoption of Emerging Technologies in Mathematics Education

Countries worldwide are increasingly integrating these technologies into their educational systems. For example, in the United States, AI-driven platforms like DreamBox Learning are used to tailor mathematics instruction to individual student needs, improving both engagement and outcomes (Anderson, Corbett, Koedinger, & Pelletier, 2020). Similarly, in Singapore, a leader in educational technology, interactive simulations and games are employed to make abstract mathematical concepts more accessible to students (Nguyen, Williams, & Slavin, 2020).

1.2 The Role of Emerging Technologies in Enhancing Accessibility and Inclusivity

The Following are the Role of Emerging Technologies and Inclusivity;

i. Enhancing Accessibility

Emerging technologies have made mathematics more accessible to a broader range of students, including those with disabilities. Tools such as screen readers, speech-to-text software, and specialized educational apps allow students with visual, auditory, or cognitive impairments to engage with mathematical content more effectively. In Nigeria, initiatives like the National Open University of Nigeria (NOUN) have incorporated these technologies to provide accessible mathematics education to students in remote and underserved areas (UNESCO, 2021).

ii. Promoting Inclusivity

Beyond accessibility, these technologies promote inclusivity by accommodating diverse learning styles and paces. Adaptive learning systems, powered by AI, offer customized learning experiences that adjust to the individual needs of each student. For instance, in the United Kingdom, systems like Smart Sparrow allow students to learn at their own pace, receiving personalized feedback and additional resources tailored to their learning needs (Ertmer & Ottenbreit-Leftwich, 2013).

1.3 Fostering Creative Problem-Solving through Technology

1. The Role of Simulations and Visualizations

Emerging technologies encourage creative problem-solving by enabling students to explore complex mathematical concepts through simulations and visualizations. Virtual reality (VR) environments, for example, allow students to manipulate and interact with geometric shapes in a three-dimensional space, fostering a deeper understanding of spatial relationships. Adegbija and Iyamu (2020) who carried out a research on the role of virtual reality in enhancing spatial reasoning skills in Nigerian Mathematics Education in University of Lagos has shown that students who use VR in their mathematics classes perform better in geometry and spatial reasoning tasks compared to those who do not.

2. Collaborative Learning Platforms

Collaborative platforms like Google Classroom and Microsoft Teams have also played a significant role in enhancing creative thinking in mathematics education. These platforms allow students to work together on mathematical problems in real-time, facilitating peer learning and the exchange of ideas. Higgins, Mercier, Burd, and Joyce-Gibbons, (2012) stated that in South Africa, the use of such platforms has been linked to improved problem-solving skills among secondary school students.

2.1 Real-Time Feedback and Adaptive Learning

A. Benefits of Real-Time Feedback

One of the most transformative aspects of emerging technologies is their ability to provide real-time feedback to students. This immediate feedback helps students correct mistakes as they occur, reinforcing learning and promoting a deeper understanding of mathematical concepts. For example, in Nigeria, the adoption of digital platforms like uLesson has enabled teachers to monitor student progress in real-time and adjust instruction accordingly (National Research Council, 2020).

B. Adaptive Learning Systems

Adaptive learning systems, which use AI to analyze student's performance and adjust the difficulty of problems accordingly, are particularly effective in mathematics education. These systems ensure that students are always working at the appropriate level of challenge, preventing frustration while promoting mastery of concepts. Anderson *et al.,* (2020) stated that in the United States, the DreamBox Learning platform has been shown to significantly improve student's achievement in mathematics by using adaptive algorithms to personalize learning.

2.2 Preparing Students for Future Challenges

i. Developing 21st Century Skills

The integration of emerging technologies in mathematics education is essential for preparing students for the demands of the modern workforce. Skills such as critical thinking, problem-solving, and digital literacy are increasingly important in a world where technology and data analysis are ubiquitous. By engaging with these technologies in the classroom, students not only improve their mathematical abilities but also develop the competencies needed for careers in Science Technology Engineering and Mathematics fields (National Research Council, 2020).

ii. Case Studies: Success Stories from Nigeria and Beyond

Several success stories highlight the impact of emerging technologies on mathematics education. For example, in Kenya, the M-Shule platform uses AI and SMS technology to deliver personalized math tutoring to students in low-income communities. This has led to significant improvements in student's performance, particularly in rural areas with limited access to traditional educational resources (Nguyen, Williams, & Slavin, 2020). In Nigeria, the uLesson platform has similarly revolutionized mathematics education by providing affordable and accessible digital lessons to students across the country (UNESCO, 2021).

2.3 Challenges and Considerations

i. Access to Technology

Despite the potential benefits, the integration of emerging technologies in mathematics education faces several challenges. One of the most significant is the unequal access to technology, particularly in developing countries like Nigeria. While urban schools may have access to the latest digital tools, rural and underserved areas often lack the necessary infrastructure to support technology-based education (Ertmer & Ottenbreit-Leftwich, 2013).

ii. Teacher Training and Professional Development

Another challenge is the need for comprehensive teacher training and professional development. Teachers must be equipped with the skills and knowledge to effectively integrate these technologies into their classrooms. In Nigeria, initiatives like the Digital Literacy Project aim to bridge this gap by providing teachers with the necessary training and resources (UNESCO, 2021).

iii. Over-Reliance on Technology

There is also a risk of over-reliance on technology, where digital tools are used as a crutch rather than a complement to traditional teaching methods. It is essential to strike a balance between the use of technology and the development of fundamental mathematical skills (Higgins et al., 2012).

2.4 Policy Implications and Future Directions

A. Government Initiatives and Support

Governments play a crucial role in supporting the integration of emerging technologies in education. In Nigeria, the Federal Ministry of Education has launched several initiatives aimed at promoting the use of digital tools in schools, including the development of ICT infrastructure and the provision of digital learning resources (National Research Council, 2020).

B. The Role of International Organizations

International organizations such as UNESCO and the OECD have also been instrumental in promoting the adoption of emerging technologies in education. These organizations provide valuable resources, research, and funding to support the integration of digital tools in classrooms around the world (UNESCO, 2021).

C. Future Research and Development

Future research should focus on the long-term impact of emerging technologies on mathematics education, particularly in developing countries. There is also a need for more studies on the effectiveness of specific technologies and their impact on student learning outcomes (OECD, 2019).

3. Conclusion

Emerging technologies have the potential to transform mathematics education by making it more accessible, engaging, and aligned with the demands of the 21st century. However, realizing this potential requires careful consideration of the challenges and a commitment to ensuring that all students have the opportunity to benefit from these innovations. As technology continues to evolve, so too must our approaches to teaching and learning mathematics.

4. Recommendations

The following recommendations were made;

1. Governments and educational institutions should invest in the necessary infrastructure to support the integration of emerging technologies in mathematics education, particularly in underserved areas.
2. Comprehensive professional development programs should be implemented to equip teachers with the skills and knowledge needed to effectively integrate technology into their classrooms.
3. Efforts should be made to ensure that all students, regardless of their socio-economic background, have access to the digital tools and resources needed for mathematics education.
4. Efforts should be made to strike a balance between the use of digital tools and the development of fundamental mathematical skills.
5. Continuous research and evaluation are needed to assess the impact of emerging technologies on students learning outcomes and to identify best practices for their integration into mathematics education.

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Article 11

Institutional Variables as Determinants of Lecturers' Job Performance in Colleges of Education in Kwara State, Nigeria

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Abstract

This study examined the relationship between institutional variables as determinant of lecturers' job performance of the academic staff in Colleges of Education in Kwara State. The study adopted descriptive survey of correlational type. The population of the study comprised 642 lecturers and 5,320 in Colleges of Education in Kwara State. Purposive sampling technique was used to select 428 lecturers and 2,760 students in Colleges of Education in Kwara State based on senatorial district. Simple random sampling technique was used to select 241 lecturers, and 333 students were selected using research advisor. The researcher adapted questionnaires tagged Institutional Variables Questionnaire" (IVQ) and "Lecturers' Job Performance Questionnaire" (LJPQ) were used. Descriptive statistics of mean and standard deviation was used to answer the research question while Pearson Product Moment Correlation was used to test the hypotheses at 0.05 level of significance. The findings of the study revealed that Institutional Variable Influences Lecturers Job Performance in Colleges of Education in Kwara State, Nigera. Therefore, it is recommended that the management of Kwara State Colleges of Education and other educational stakeholders are to stand up and put all hands on deck against the challenges ahead of them on improving the colleges on the institutional variables which might impede their productivity.

Keywords: Institutional Variables, Colleges of Education, Lecturer, Job Performance

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1. Introduction

Human and material resources are very essential for the overall development of education at all level. Muhammad (2021) asserted that human and material resources provide a healthy learning environment for lecturers and students alike in the tertiary Institution. They are also expected to engender a safe and conducive learning environment for the lecturers and other employees of the colleges of education towards driving home the goals of tertiary education. Chuktu, Owan, and Aduma (2023) observed that, the lecturers of tertiary institutions are central in driving the core mandate of colleges of education and higher education towards goal attainment. Under normal circumstances, lecturer should discharge their duties effectively and with a high compliance rate with stated rules and expected behaviour patterns. In doing this, lecturer should be able to contribute to students' personal and career development by modifying their attributes (across the three domains of learning) and preparing them for a useful living. They explained further that academic staff should also be able to participate in research-driven endeavours by identifying problems and engaging in studies to address such concerns. The outputs of such research exercises were expected to be published in top-ranking journals to boost the prestige of both members of the research team and the institution where they work.

Furthermore, lecturers were expected to engage in activities other than teaching and research, which is necessary to support students, colleagues, managers and the school environment. Okolie (1995), regardless of lecturers' pre-service training level, there is a need for every lecturer to constantly renew, upgrade and update his/her knowledge, skills and capability in order to keep peace with the rapidly changing society. The most important agent for accomplishing the goals for the establishment of any higher institution are the lecturers whose contribution to the attainment of these goals largely depends on their knowledge, skills and competences which translate into better job performance. The job performance of lecturers implies duties performed by them at a period in the school system (Adeyemi, 2010). Lecturers' performance can be measured in terms of teaching, lesson preparation, mastery of subject matter, competence, commitment to job, effective supervision and monitoring of students' work, class control and disciplinary activity (Adeyemi, 2010).

Sadly, observations and experiences tend to contrast these expectations and staff inputs in the service delivery process in colleges of education in Nigeria (Chuktu, Owan, Peter & Aduma, 2023). Haliso & Toyosi (2013) expressed that the performance expected of some lecturers are not there, due to inadequate modern-day facilities such as the internet facilities, well equipped library, unconducive working environment, inadequacy of priority in staff development and multiple jobs to be carried out within a stipulated period of time. Also, Carol and Perpetua (2014) asserted that overcrowding of lecturers' offices, inadequate modern gadgets with irregular power supply, overcrowded classrooms without adequate and functional internet facilities among others contribute to lecturers' inability to discharge their duties as expected of them. Noel (2016) revealed that if teachers are overloaded, their overall efficiency decreases, and teachers who are given appropriate loads are likely to attain a better level of teaching performance. The amount of classroom work assigned to an average teacher should be limited because when more is expected of him, either the quality of work or the health of the teacher is impaired Orais in (Noel, 2016). Unfortunately, the rate at which teaching staff are recruited by institutions does not appear to measure up with the work load created by this voracious search for knowledge via Institution. The implication has been that of inadequate man power, and excess work load for those available.

Most staff have complained that the poor funding of education in Nigeria, which resulted in the poor provision of required facilities, is one of the reasons why they are dissatisfied with their jobs (Chuktu, Owan, Peter & Aduma, 2023). Others have pointed accusing fingers at the poor and inconsistent remuneration packages offered to them as insufficient for family maintenance, let alone research endeavours (which is financially demanding). Some have also attributed their poor research engagement to the lack of grant opportunities as a reason for their low compliance (Chuktu, Owan, Peter & Aduma, 2023). However, there are some developments, such as grant provision and funding that the school and researchers are expected to explore to see corresponding improvements in the provision of facilities, staff service delivery and so on. For instance, the TETFund provides huge annual grants to school and researchers alike for conducting small- and large-scale research. Despite the huge governmental interventions in tertiary institutions through Tetfund and the like annually, educational problems still remain pervasive: yearly increasing students enrolments, inadequate infrastructures, inadequate staff development programmes, inadequate work-aid facilities such as internet facilities, well equipped library and declining lecturer-student ratios, in the same vain, lecturers are given more assignment aside their core primary assignment in terms of number of courses taking, which rendered them to be counterproductive.

However, there are researches on institutional Variables and lecturers' Job Performance; such as; Abosede and grace (2016) carried out a study on workload related stress and job effectiveness of university lecturers in Cross River State, Nigeria. Also, Issa (2016) investigated on institutional development and lecturers' effectiveness in Universities in Kwara State. Peretomode and Chukwuma (2014) also examined the relationship between manpower development and lecturers' productivity in tertiary institutions in Nigeria. It is noteworthy that no study to the beset of researcher's knowledge has focused specifically on institutional variables as determinant of lecturers' job performance, especially in Colleges of Education in Kwara State, Nigeria. Moreover, the previous researches centered on isolated variable and not a combined measure of the independent variable of the current study; this study focuses on three sub variables (staff development, workload, and internet facilities). These are some of the missing gaps this study intends to proffer solution to.

2. Literature Review

Various researches have been carried out on variable that might influence teachers' job satisfaction or performance which are termed "institution variable" (Maenpaa, 2005). Those variables include: school-specific factors like availability of material resources, teacher-students' ratio, school environment, and school culture, prompt payment of salary, organizing seminars and conferences and feelings of successful teaching, school internet facilities, workload among others. Interestingly, teachers have different factors that could influence their job satisfaction thereby deterred their performance. For instance, prompt payment of salary might be an influencing factor to a teacher, while school environment might be an influencing factor to another. Job satisfaction has been demonstrated to be closely related to commitment, turnover, job performance, productivity and turnout (Cooper & Kelly, 1993).

In fact, labour turnover, as a problem in an organisation, had been researched on by various scholars (Katers, 2012; Shaw, John, Jerkins, & Nina, 1998; Booth & Hamer, 2007; Maryin, 2003). Labour turnover or "brain drain" is one of the major challenges facing education in Nigeria today. Labour turnover intentions seem to be varied and prevalent in tertiary institutions of both the federal owned and state owned. As tertiary educational systems grow and diversify, society is increasingly concerned about the quality of her programmes. Much attention is given to public assessments as well as international rankings of these institutions for quality assurance, but less attention is paid to what play with the individuals that are made up of the institutions.

Although, these assessments and rankings tend to overemphasize more on research, using research performance as a yardstick of institutional value; measuring teaching quality is a challenging task. Teaching ought not to be seen as increasingly relative to the research goals of an institution; rather educational institutions should be recognized for being providers of good quality education particularly, at the tertiary level of learning in order to actualize the much desired scientific and technological growth and development, specifically, the colleges of education. As such, there is a need to find new ways of measuring and demonstrating performance, which is also not unconnected to educational resources available for lecturers to perform optimally. Researchers have linked performance in higher education with student intake, academic programs, program designs, lecturers' workload, teaching and learning, students' experiences and academics and non-academic support for the students (Baird, 2006). Adetoro (2009) classified these educational resources into human, physical and financial resources. These are potential inputs of the institution that enable the institution to achieve its stated objectives, if they are effectively managed. They are the pre-conditions for successful implementation of school programmes and whenever this condition is not fulfilled, the ability of the teaching staff to perform his/her task will be greatly hampered. Vathanophas and Thai-ngamare (2007), asserted that competent employees are the main resource of any organization in acquiring a competitive advantage. Land, buildings or materials do not yield company productivity, rather, it is peoples' capital of effort and commitment that runs a business and produces value from existing resources. HayGroup (2004) point out that an organization's best source of competitive advantage lies with its employees. Strategies, business models, products and services can all be copied by competitors, but talented and competent employees represent a sustainable source of differentiation

2.1 Lecturers' Job Performance

Nigerian higher education stakeholders are greatly concerned about the quality of education provided to the citizens of the country. Concerns about the quality of education students receive from universities, the quality of lecturers (teaching staff) employed to teach students, the quality of infrastructures and instructional facilities have always been of upmost interest. Quality teaching has become an issue of importance as the landscape of higher education has been facing continuous changes: increased international competition, increasing social and geographical diversity of the student body, increasing demands of value for money, introduction of information technologies. Researchers have linked quality in higher education with student intake, academic programs, program designs, lecturers' workload, teaching and learning, students' experiences and academics as well as non-academic support for the students (Baird, 2006). Baird (2006) maintains that quality in higher education relates to development of intellectual independence.

Though, quality teaching lacks a clear definition, because quality can be regarded as an outcome or a property, or even a process, and because conceptions of teaching quality happen to be stakeholder relative. Henard and Leprince-Ringuet (2008). They also opined that quality teaching initiatives are very diverse both in nature and in function. Some of these initiatives are undertaken at teachers' level, others at departmental, institutional or country level. Some quality initiatives aim to improve pedagogical methods while others address the global environment of student learning. Some are top-down process, other induce grass-root changes. The most currently used quality initiatives seem to aim to enhance teamwork between teachers, goal-setting and course plans.

However, scholars have developed holistic theoretical models of how quality teaching initiatives should unfold. Gathering information and reading the literature – looking outside the classroom – are important tools to improve quality teaching, but they are still under-employed. Another important point to keep in mind is that in order for student learning to be enhanced, the focus of quality teaching initiatives should not always be on the teacher. Rather it should encompass the whole institution and the learning environment. Changes in the funding structure of many institutions also increased the focus on the quality of teaching.

Higher Institutions must learn to respond to these concerns about finances. Moreover, higher education is increasingly seen as an investment that should contribute to national prosperity in the long term. Therefore, the return on the investment must be good (Yorke, 2000). Quality assurance in higher education has also become a focus of attention for private universities (Jones, 2003). Students - who are increasingly paying tuition fees- might now be considered as "clients" of higher education institutions (Telford & Masson, 2005). Students are therefore also very concerned about the quality of the lectures they pay for. As the "culture of higher education" has become "increasingly market-oriented" (Green, 1993), external demands for quality of teaching have increased.

Recently there has been a renewed interest in the debate about quality and quantity of research output and the factors which influence output of university lecturers (Goodyear, 2006; Hemmings & Kay, 2008; Yates, 2005). At the same time, an intensification of the work of lecturers has made the decision to balance research, teaching, and service activities for many of these lecturers more difficult (Blackmore & Sachs, 2007). This is particularly critical in the case of early career academics who usually face weighty teaching loads (Lucas & Turner, 2007), undergo close surveillance by their senior colleagues (Baron, 2000), carry their own high expectations and those of others, their students for instance and may have restricted access to resources (Bazeley, 2003).

These competing pressures make balancing research, teaching, and service a very perplexing task and, within the busyness of university work, leave little time for academicians to make a considered decision about their own professional development. Furthermore, the recent overriding emphasis on the quality and impact of research (Bai, Millwater, & Hudson, 2008) has made the decision more complex. Increasingly, universities, or at least their managers, are being rewarded for research output, innovation, and application and, as a result, this 'reward' climate is placing a further strain on university lecturers.

College managers need to recruit, develop, and retain lecturers with a high level of research activity. Watty, Bellamy and Morley (2008) pointed out the importance of job satisfaction, being part of a community of scholars, and having relative autonomy and flexibility in the way they work. These same researchers also highlighted that committed researchers give higher priority to research than their other work-related tasks. Similarly, committed teachers demonstrate a stronger affiliation to teaching than other tasks. University managers would benefit from a more thorough appreciation and understanding of the factors that influence such career decisions. The unifying model has the potential to address this matter.

2.2 Pedagogical Content Knowledge

Barnstein (2006) sees Instructional delivery as a process of logically presenting instruction in line with the subject matter to the students. The author noted further that instructional delivery methods are designed to be as interactive as possible, emphasizing small group work using relevant and practical case studies. An important part of any teaching experience is the quality of the relationship between learners and teachers. When appropriate instructional method system is adopted for imparting relevant skills, knowledge and attitudes to the learners, efforts must be made by the teachers to adopt the use of the most relevant instructional method system (UNESCO, 1999). Magnusson, Krajcik and Borko (1999) is helpful in clarifying this special form of a teacher's professional knowledge by proposing that PCK is made up of five components. In their view, an experienced teacher's PCK encompasses his/her:

- orientations towards teaching (knowledge of and about their subject and beliefs about it, and how to teach it);
- knowledge of curriculum (what and when to teach);
- knowledge of assessment (why, what and how to assess);
- knowledge of students' understanding of the subject; and
- knowledge of instructional strategies.

Webbstock (1999) underlines that good teaching is a type of teaching that correlates with the educational institution's mission statement. Hativa (2001) focus their attention on four components: lesson organization, lesson clarity, interest in learning, and positive classroom climate. Taylor (2003) lists thirteen abilities needed for Quality Teaching and learning: Engagement locally and globally, Engagement with peers and colleagues, Equity and pathways, Leadership, Engagement with learners, Entrepreneurship, designing for learning, teaching for learning, Assessing for learning, Evaluation of teaching and learning, Reflective practice and professional development, Personal management, and Management of teaching and learning.

Engin-Dermir (2009) opined that lecturers play crucial roles in promoting educational growth and performance. He affirmed that teacher's qualification, knowledge of the subject matter, enthusiasm, interaction with students, method of lecture delivery and encouraging participation in discussions have positive and significant impact on students' achievements. Engin-Demir (2009) therefore recommended the need for the use of appropriate teaching methods, facilities and basic electronic components by teachers to facilitate learning. They emphasized the dramatic effect this has on the students in terms of increased learning and performance. In the same vein, Gainen (1995) recommended the need for inclusive teaching and learning approaches responsive to the varying levels of academic needs. These according to them provide sites for interactions between staff, students and institutional structures. Since institutional facilities have a great impact on students' academic performance, universities should be committed and willing to develop strategies that can facilitate learning within their environments.

2.3 Conceptual Frame Work of the Study

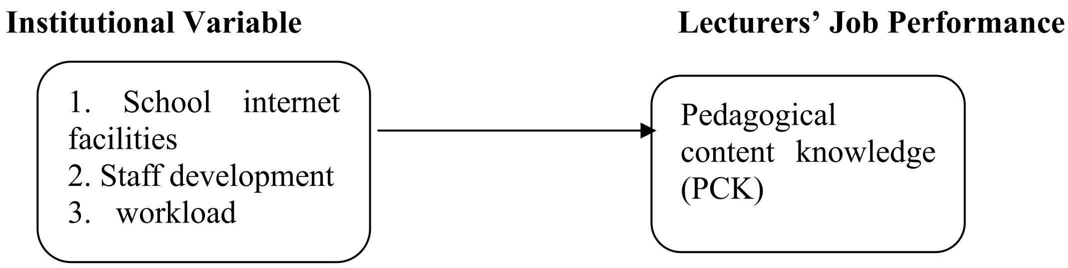

Figure 1: Institutional Variables and Lecturers' Job Performance Model
Source: Designed by researcher, 2019

The conceptual framework in figure 1 shows the relationship between institutional variables as determinant of lecturers' Job Performance in Colleges of Education in Kwara State. Institutional variable constitutes the inputs in the colleges of education programme. These institutional variables are all educational resources that are used directly and indirectly for the purpose of facilitating, influencing or encouraging transmission or acquisition of knowledge, competence and skills. It is form of human and non-human resources. Human resources cover the lecturers that is, workforce development: In-service training, seminars, workshops, conferences and workload while non-human resources are physical and material resources such as infrastructural facilities: good roads network, water supply, electricity, instructional materials, well-furnished offices, internet facilities as well as equipped laboratory and library. The teaching (lecturing) that is, transmission of knowledge as the process, it is understood that resources are indispensable tools in acquiring knowledge, skills competence by the students but there is also the need for effective and efficient utilization of these available resources by the lecturers. The outcome of from the finding is expected to improve quality and assist the lecturers to perform better and produce competent students in the society. Lastly, the model shows that there is need to effectively utilize the resources provided in an institution by the lecturers through teaching (lecturing) and classroom management that will bring effective and efficient job performances in colleges of education.

3. Methodology

The research design adopted for this study was survey of correlational type with a population 642 lecturers and 5,320 students of eight Colleges of Education in Kwara State. Thus, the target population for this study consisted of 428 lecturers and 2,760 students in the three purposively selected Colleges of Education (Kwara State College of Education, Ilorin., Kwara State College of Education, Oro., and Kwara State College of Education (Technical), Lafiagi) in Kwara State based on senatorial district. One hundred and ninety-six (196) academic staff, and 333 students were selected using research advisor (2006) table of determining sample size. Proportional sampling technique was used in selection of number of lecturers and students per each of the institution selected for this study. While simple random sampling technique was used for the selection of the respondents (lecturers and students) from each of the colleges of education. The researcher adapted questionnaires tagged Institutional Variables Questionnaire" (IVQ) and "Lecturers' Job Performance Questionnaire" (LJPQ). In order to ascertain the validity of the instruments used for data collection for the study, copies of IVQ and LJPQ were given to two lecturers in the field of Educational Management and experts and practitioners assisted in determining the face and content validity of the instrument by ensuring that it is clear, unambiguous and relevantly covered the major variables in the study. Also, the instrument was pilot tested and it yielded a reliability coefficient of 0.81. The data gathered for the study were analyzed using Statistical Package for Social Sciences (SPSS).

4. Results and Findings

Ho: There is no significant relationship between institutional variables and lecturers' job performance in Kwara State Colleges of Education

Table 1: Institutional Variables and Lecturers' Job Performance in Kwara State Colleges of Education.

Variable	N	Mean	SD	Df	Cal.r-value	p-value	Decision
Institutional Variables	220	11.42	2.31	218	.98	.137	**H_{o1}:** Accepted
Lecturers' Job Performance	220	48.78	12.76				

***Significant ρ< 0.05**

Result from Table 3 indicated the Pearson correlation analysis value yielded r = 0.198 which is positive relationship with p value .137 > 0.05. This shows a positive non-significant relationship result. Hence, the hypothesis was accepted. This implies that a positive not significant relationship exists between institutional variables and lecturers' job performance in Kwara State Colleges of Education.

Ho1: There is no significant relationship between school internet facilities and lecturers' job performance in Kwara State Colleges of Education.

Table 2: School Internet Facilities and Lecturers' Job Performance in Kwara State Colleges of Education

Variable	N	Mean	SD	Df	Cal.r-value	p-value	Decision
School Internet Facilities	220	12.47	2.34	218	.079	.223	**H_{o1}:** Accepted
Lecturers' Job Performance	220	48.78	13.78				

***Significant ρ< 0.05**

Result from Table 4 revealed the Pearson correlation analysis value yielded r = 0.079 which is positive relationship with p-value .223 > 0.05. This indicated a positive non-significant relationship result. Thus, the hypothesis was accepted. This means that a positive not significant relationship exists between school internet facilities and lecturers' job performance in Kwara State colleges of education.

Ho2: There is no significant relationship between staff development and lecturers' job performance in Kwara State colleges of education.

Table 3: Staff Development and Lecturers' Job Performance in Kwara State Colleges of Education

Variable	N	Mean	SD	Df	Cal.r-value	p-value	Decision
Staff Development	220	14.45	3.32	218	.042	.496	**H_{o1}:** Accepted
Lecturers' Job Performance	220	50.71	14.76				

***Significant ρ< 0.05**

Result from Table 6 indicated that the Pearson correlation analysis value yielded r = 0.042 which is positive association with p value .496 > 0.05. This shows a positive non-significant relationship result. Therefore, the hypothesis was accepted. This implies that a positive not significant relationship exists between staff development and lecturers' job performance in Kwara State colleges of education.

H3: There is no significant relationship between workload and lecturers' job performance in Kwara State colleges of education.

Table 4: Workload and Lecturers' Job Performance in Kwara State Colleges of Education

Variable	N	Mean	SD	Df	Cal.r-value	p-value	Decision
Workload	220	14.45	3.32	218	.071	.269	**H_{o1}:** Accepted
Lecturers' Job Performance	220	50.71	14.76				

Table 4 showed that the Pearson correlation analysis value yielded r = 0.071 which is positive relationship with P value .269 > 0.05. This means a positive not significant relationship result. Hence, the hypothesis was accepted. This shows that there is a positive not significant relationship between workload and lecturers' job performance in Kwara State colleges of education.

5. Discussion of the findings

The main and operational hypotheses were tested using the Pearson's Product Moment Correlation statistical tool, to determine whether there existed significant relationship between institutional variables and lecturers' job performance in Colleges of Education in Kwara State. The result from Table 1 indicated the Pearson's correlation analysis value yielded r = 0.98 which is a positive relationship with p value .137 > 0.05. Hence, the hypothesis was accepted. This implies that there is no significant relationship between institutional variables and lecturers' job performance in Kwara State Colleges of Education. Meaning that the institutional variables of Internet facilities; staff development and lecturers' workload of the colleges sampled had no significant relationship with the job performance of the lecturers, the positive relationship implies that the more the institutional variables are improved the better the job performance of the lecturers as supported by Hameed and Amjad (2009) that better outcomes and increased productivity is assumed to be the result of better workplace environment and better physical environment of office boosts the employees and ultimately improve their productivity. It is paramount that college lecturers get supportive and sufficient office facilities which promote productivity.

Result from Table 2 revealed that the Pearson's Correlation analysis value yielded r = 0.079 which is a positive relationship with p-value .223 > 0.05. This indicated a non-significant relationship result. Thus, the hypothesis was accepted. This means that there was no-significant relationship existed between school Internet facilities and lecturers' job performance in Kwara State colleges of education. This is due to the fact that Internet facility has not been fully incorporated to the extent that lecturers' will now rely on to measure their performance when the colleges under study are still battling with epileptic power supply which will enhance the use of the Internet facilities in the school. The positive relationship shows that availability of Internet facilities in the colleges under study will raise and improve the lecturer's productivity in terms of his job performance. In the work of Akpan (2014) the positive relationship of Internet facilities and job performance were supported as Akpan opined that lecturers equipped with Internet facilities were found to be more efficacious in classroom instruction, research/publication, communication and recordkeeping than those with moderate and low Internet facilities. The findings of this study revealed that the provision of internet facilities for lecturers will positively enhance their job performance in the Colleges. More so, availability and use of Internet facility by higher institution of learning teachers will reduce the lecturer's workload (Omenyi, Aju & Odimegwu, 2007).

There is no significant relationship between staff development and lecturers' job performance in Colleges of Education in Kwara State. Result from Table 3 indicated that the Pearson correlation analysis value yielded $r = 0.042$ which is a positive association with p value $.496 > 0.05$. This shows a non-significant relationship result. Therefore, the hypothesis was accepted. This implies that there is non-significant relationship exists between staff development and lecturers' job performance in Colleges of Education in Kwara State. This finding is supported by the study carried out by Suleiman (2015), where he reported that participation in seminars and workshops, conferences, higher education and ICT programmes have several positive effects on the job performance of lecturers in the Federal Polytechnics, including: gaining of new knowledge and skills that enable them perform their tasks better with job satisfaction and motivation. It was however found that the management of the college of education did not adequately support staff development. The attitude of lecturers towards attendance and participation in conferences was positive and there were organisational issues that constrain staff development in the college of education. Hence, the positive relationship indicates that when staff development is improved that lecturers attend seminars, workshop and conferences will have a positive improvement on the job performance of the lecturers (Nzoka, 2015).

Table 4 showed that the Pearson's correlation analysis value yielded $r = 0.071$ which is a positive relationship with P value $.269 > 0.05$. This means there was no significant relationship. Hence, the hypothesis was accepted. This shows that there is a positive not significant relationship between workload and lecturers' job performance in Colleges of Education in Kwara State. The implication of the result is that when there is increased lecturer's work will lead to increased job performance as supported by the study carried out by Amalu (2004) that teachers are not affected by workload, also supported is the result from the finding of the Australian Council for Educational Research (ACER) 2004 that mainly the Heads of departments (Managers) were clearly the group most affected by workload and not the academic staff. This is contrary to the findings of Agulanna (2007) and Denga and Ekpo (1994). Their finding was also affirmed by Jega (2002); Nelson and Quick (2003) and Tiji (2000) that found that workload adversely affects job performance.

6. Conclusion

The following conclusion were reached from the research findings: various form of institutional variables was observed in Colleges of Education in Kwara State aside from the one understudy (school Internet facilities, staff development and workload on the job performance of lecturers). The job performance was measured using lecturers' pedagogical content knowledge (PCK). It was gathered from this study that all the institutional variables in the study have no significant relationship with the lecturers' job performance. This does not mean that they are not at all related to lecturers' job performance but have low significant relationship. The implication of this is that, they are still related to job performance of which, there is need for improvement in most of the institutional variables available to Colleges of Education in Kwara State as mentioned in the research work. The study was not only being isolated based on the results from the study but also supported by many literatures related to the variables of study. It is from this that the recommendations were made.

7. Recommendations

Both managers and individual academic staff should play an active role in managing workloads through advocacy for the needed changes to institutional practice, programme delivery patterns, and reconsideration of activities that detract from the fundamental purposes of higher education. Ultimately, it is the individual managers and faculty who must assume responsibility for shaping their role and academic work profile. Among other recommendations;

1. Despite the fact that the lecturers are doing well in their work, there is still room for improvement. Hence, there is need for the government and the management of the Colleges of Education to get the lecturers highly motivated for more effectiveness.
2. It is imperative that the government and the Colleges of Education management encourage lecturers by providing conducive environment for teaching and research such as Internet facilities, e-library, restricted published research content to enhance effective teaching and learning.
3. There is need for the management of the Colleges of Education to make fund available for the training and retraining of lecturers, support them with adequate research grants since it increases lecturers' and organizational visibilities and ranking.
4. The management should create more time for Colleges of Education lecturers through reducing their workload. To achieve this, there is need for the employment of additional lecturers as to bring about proper distribution of administrative jobs.

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Article 12

Integrating Aquaculture into Stem Curriculum: Effect of Different Processing Techniques on the Nutritional and Antinutritional Composition of the Egyptian Riverhemp (*Sesbania sesban*)

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Abstract

This study evaluated the effect of different processing techniques on the nutritional and antinutritional composition of *Sesbania sesban* with the aim of incorporating this unconventional feed material into aquaculture. 6 kg *S. sesban* seeds were thoroughly picked and divided equally into 5 portions of 1.2kg each. One portion was kept raw, the second portion was soaked in water, the third portion was boiled at 100^0c in water, the fourth portion was fermented, and the fifth portion was roasted. All five portions were milled into powder and thereafter taken to the laboratory for proximate and antinutrient analysis. The analysis of raw and processed *S. sesban* showed significant differences ($P<0.05\%$) in the nutrient and antinutrient composition of samples. Fermented *S. sesban* had the highest crude protein content at 37.50% while soaked sample exhibited the highest crude fibre content at 15.40%. Raw sample exhibited the highest crude lipid content at 23.75% as well as the highest NFE at 23.09% while ash content was observed to be highest in the roasted sample at 5.39%. Antinutrient analysis showed that raw *S. sesban* exhibited the highest levels of all anti-nutrients; Phytic Acid (0.12 mg/100 mg) Trypsin Inhibitor (9.23 mg/100 mg) Tannins: (3.20 mg/100 mg) Saponins (8.05%) oxalates (0.07g/kg) and alkaloids (2.60) which significantly decreased after processing. This emphasizes the potential benefits of integrating aquaculture projects into STEM curricula. A structured curriculum that incorporates aquaculture projects, outlining clear learning objectives and assessment criteria will help enhance student learning and practical application of scientific principles to problem-solving.

Keywords: Antinutrients, Nutrients, Processing technique, *Sesbania sesban*, STEM curriculum integration

1.Introduction

Aquaculture is the fastest growing food production sector globally (FAO, 2020), it plays a vital role in poverty alleviation and food security programs (FAO, 2016). With a rising demand for fish protein, the cost of fish feed ingredients, particularly high-quality sources like soybean meal, is a major constraint for the industry (Bolorunduro & Adikwu, 2016). This competition for resources between humans, livestock, and aquaculture pushes prices even higher (Dronne, 2018). Egyptian river hemp (*Sesbania sesban*) is a fast-growing, leguminous, multi-purpose plant native to Africa and widely cultivated throughout tropical and subtropical regions (Abdelgawad *et al*., 2023) see figure 1. *Sesbania sesban* seeds are known for their high protein content, making them a valuable source of nutrition in animal feed. Studies have shown that the crude protein content of *Sesbania sesban* can range from 30-40% depending on the processing methods used (Singh & Srivastava, 2024). This makes it a promising legume for addressing protein deficiencies in fish diet (Chikagwa-Malunga,2018). However, plant-based protein sources often contain anti-nutritional factors (ANFs) that can hinder nutrient utilization and fish health (Punia & Singh 2024).ANFs are biological components in food that reduce nutrient utilization or food uptake, impair gastrointestinal functions, and affect metabolic performance. Several ANFs irritate the intestinal lining or cause excess mucus production, disrupting gut function and hindering nutrient absorption (Abu-hafsa *et al*., 2022). Fortunately, many ANFs can be reduced or eliminated through various processing techniques. This study aims to evaluate the effect of processing on the nutrients and anti-nutritional composition of Egyptian riverhemp *(sesbania sesban*) as a potential substitute plant protein source in fish diets.

Figure 1. *Sesbania sesban* plant with fresh leaves and dried pods

2.Materials And Method

2.1 Collection of seeds

Sesbania sesban seeds were collected from Amshi, Jakusko Local government area of Yobe State. The area is located at latitude 12.71027^0 N and longitude 10.87593^0 E.

2.2 Experimental Site.

The laboratory analysis was conducted at the Biochemical laboratory unit of the department of animal science, Faculty of Agriculture, Ahmadu Bello University, Zaria. The area is located at latitude 11◦09' 06'' N and longitude 7◦ 38' 55'' E.

2.3 Experimental Design

Six kilograms (6kg) of *Sesbania sesban* seeds (Figure 2) were thoroughly picked and divided equally into 5 portions. 1.2kg of raw *Sesbania sesban* seeds were milled and labeled as sample A (Figure 3). Another 1.2kg of the seeds were boiled for 1hour 30 minutes at 100^{o}C, the boiled seeds were later sun-dried for 1 day (Figure 4) and milled into powder using hammer mill and labeled as sample B (Figure 5). The third 1.2kg of seeds were cleansed, washed and soaked in water for 24 hours. The soaked seeds were dried for 1 day (Figure 6) and milled into powder and labeled as sample C (Figure7). The fourth 1.2kg seeds were boiled for 1 hour at 100^{o}C and kept in an airtight container to ferment for 72hours. The fermented seeds were washed and sun-dried for 1 day (Figure 8), then milled into powder and labeled as sample D (Figure 9). Lastly, the fifth 1.2kg of the seeds were stir roasted in an open pan for 30minutes (Figure 10). The roasted seeds were set aside for 1 hour then milled into powder and labeled as sample E (Figure 11).

Figure 2. Raw *Sesbania sesban* seeds

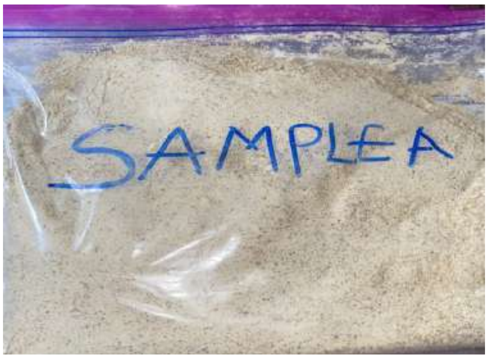

Figure 3. Raw *Sesbania sesban* meal

Figure 4. Boiled *Sesbania sesban* seeds

Figure 5. Boiled *Sesbania sesban* meal

Figure 6. Soaked *Sesbania sesban* seeds

Figure 7. Soaked *Sesbania sesban* meal

Figure 8. Fermented *Sesbania sesban* seeds

Figure 9. Fermented *Sesbania sesban* meal

Figure 10. Roasted *Sesbania sesban* seeds

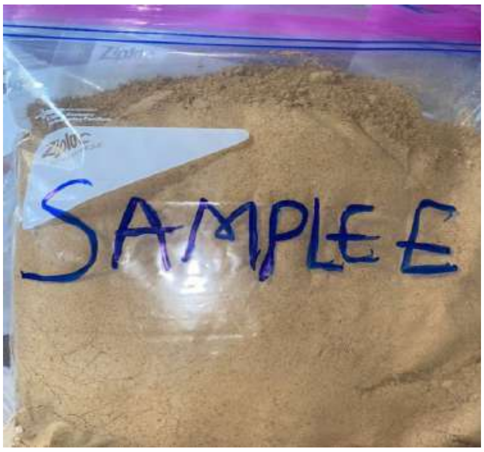

Figure 11. Roasted *Sesbania sesban* meal

2.4 Proximate Analysis

The proximate composition of the raw and processed Sesbania sesban seed powders were analysed. crude protein, crude lipid, crude fibre, ash content and Nitrogen free extracts (NFE) were determined following AOAC (1990).

2.5 Antinutrient analysis

Anti-nutritional factors Phytates and Oxalates were determined using the Isocratic High Performance Liquid Chromatography (HPLC) as described by Onwuka, (2005). Tannins and Trypsin inhibitors were determined according to AOAC, (2000), alkaloids and saponins were determined following methods described by Harborne, (1973). Hydrogen cyanide was determined following AOAC, (1995).

2.6 Data Analysis

Difference among dietary treatment means were tested by one way Analysis of Variance (ANOVA), and means were compared using Turkey's Multiple Comparison Test (Steele and Torrie, 1960) to test for significance of variation between the means and differences will be considered significant at $p < 0.05$

3.Results

3.1 Nutrients Contents of Processed Egyptian riverhemp Seed Meal.

The proximate composition of raw and processed Egyptian riverhemp is Presented in Table 1: Fermented Egyptian riverhemp had the highest crude protein content at 37.50%, followed by the roasted sample at 36.90%. The raw sample had the lowest crude protein content at 35.75%. The boiled sample exhibited the highest crude fibre content, while the roasted sample had the lowest. The highest crude lipid content was observed in the raw sample. However, it decreased with various processing techniques. The ash content was highest in the roasted sample at 5.39% and lowest in the raw sample. The raw sample had the highest NFE, while the soaked Egyptian riverhemp had the lowest. Significant differences (P>0.05%) were observed among all the samples.

Table 1 Proximate Composition of Raw and Processed Egyptian riverhemp seed meal.

Processing methods					
Constituents	**A (Raw)**	**B (Boiled)**	**C (Soaked)**	**D (FM)**	**E (Roasted)**
Crude protein	35.75 ± 0.03^{e}	36.50 ± 0.07^{d}	36.82 ± 0.07^{c}	37.50 ± 0.07^{a}	36.90 ± 0.07^{b}
Crude Fibre	14.63 ± 0.02^{e}	15.40 ± 0.03^{a}	14.94 ± 0.03^{d}	15.20 ± 0.03^{b}	15.10 ± 0.03^{c}
Crude Lipid	23.75 ± 0.01^{a}	20.53 ± 0.03^{b}	20.27 ± 0.03^{c}	20.98 ± 0.03^{a}	19.92 ± 0.03^{e}
Ash	2.78 ± 0.00^{b}	4.51 ± 0.00^{d}	4.42 ± 0.00^{e}	4.53 ± 0.00^{c}	5.39 ± 0.00^{a}
NFE	$23.09.10\pm0.01^{b}$	22.55 ± 0.00^{a}	19.68 ± 0.01^{e}	20.45 ± 0.01^{d}	21.03 ± 0.01^{c}

Means on the same row with the same superscripts are not significantly different (p<0.05)

3.2 Anti-Nutrients Contents of Processed Egyptian riverhemp Seed Meal.

Table 2 presents the anti-nutrient composition of raw and processed Egyptian riverhemp. The raw sample exhibited the highest levels of all anti-nutrients, which significantly decreased after processing. The results for Phytic Acid indicate that the initial composition was at 0.12 mg/100 mg in the raw state, it decreased to 0.10 mg/100 mg (boiled), 0.08 mg/100 mg (soaked), 0.09 mg/100 mg (fermented), and 0.09 mg/100 mg (roasted). Similarly for the Trypsin Inhibitor**,** starting at 9.23 mg/100 mg in the raw sample, it reduced to 8.50 mg/100 mg (boiled), 8.30 mg/100 mg (soaked), 7.30 mg/100 mg (fermented), and 7.50 mg/100 mg (roasted). Tannins**:** Originally at 3.20 mg/100 mg in the raw state, values dropped to 1.30 mg/100 mg (boiled), 1.00 mg/100 mg (soaked), 2.60 mg/100 mg (fermented), and 0.50 mg/100 mg (roasted). Saponins**:** From an initial 8.05%, levels decreased to 7.50% (boiled), 3.30% (soaked), 0.01% (fermented), and 0.03% (roasted). Similar trends were observed for oxalates and alkaloids, showing a consistent reduction in all processing methods. Detailed results are available in Table 2

Table 2 Anti-Nutrients Contents of Processed Egyptian sesban Seed Meal.

TREATMENTS					
ANTI-NUTRIENTS	**A (Raw)**	**B (Boiled)**	**C (Soaked)**	**D (FM)**	**E (Roasted)**
Phytic acid (mg/100g^{-1})	0.12^{a}±0.01	0.10^{b}±0.00	0.08^{d}±0.00	0.09^{c}±0.02	0.09^{c}±0.00
Trypsin inhibitor (mg/100g^{-1})	9.23^{a}±0.02	8.50^{b}±0.00	8.30^{c}±0.00	7.30^{d}±0.02	7.50^{e}±0.00
HCN (mg/1mg^{-1})	3.40^{a}±0.02	2.00^{b}±0.03	1.00^{c}±0.03	0.20^{e}±0.01	0.50^{d}±0.03
Tannins (%)	3.20^{a}±0.01	1.30^{c}±0.01	1.00^{d}±0.01	2.60^{b}±0.01	0.50^{e}±0.00
Saponins (%)	8.05^{a}±0.00	7.50^{b}±0.00	3.30^{c}±0.00	0.05^{e}±0.00	0.20^{d}±0.00
Oxalates (g/kg^{-1})	0.07^{a}±0.02	0.02^{c}±0.04	0.03^{b}±0.04	0.01^{d}±0.02	0.03^{b}±0.04
Alkaloids	2.60^{a}±0.03	2.08^{e}±0.25	2.20^{c}±0.25	2.16^{d}±0.02	2.60^{a}±0.25

Means on the same row with the same superscripts are not significantly different ($p<0.05$)

FM-Fermented

HCN-Hydrogen cyanide

4.Discussions

The highest crude protein observed in fermented Egyptian riverhemp could be attributed to increase in microbial mass during fermentation causing extensive hydrolysis of the protein molecules to amino acids and other simple or lower molecular weight peptides. It may be due to the structural proteins that are integral part of the microbial cells (Tortora *et al*., 2002). The level of crude protein composition observed in this study were comparable to the content (36-40%) reported for soybean by Eshun, (2012). The percentage crude protein compositions in the unprocessed and processed samples are reasonable enough to consider the seeds of this plant (*Sesbania sesban*) a good source of protein. Since most plant feedstuffs are low in protein, thus supplementing with seeds of *Sesbania sesban* may be necessary and may contributes to the overall wellbeing of fish.

Dietary fibre is the edible part of plant-based feed materials which is essential for the health of many species of fish (particularly herbivores and omnivores) and may be beneficial for intestinal motility and health in some carnivorous fish (Li and Komarek, 2017) and promote beneficial physiological wellbeing of fish. The boiled sample exhibited the highest crude fibre content (15.40±0.03%), while the roasted sample had the lowest (15.10±0.03%). The levels of crude fibre in this study corroborate with previous findings of (Arekemase *et al*., 2013). The decreased levels of dietary fibre content in fermented *Sesbania sesban* agreed with the findings of Eka, (1980), Oboh, (2006) and Butt and Batool, (2010) that fermented foods such as legumes has lower fibre content. This observation could be due to the utilization of oxidized lipids to generate energy for the growth and the cellular activities (Sanni and Ogbonna, 1991).

Lipid inclusion in fish feed is very necessary, because aside carbohydrate, lipids are high energy yield food molecules, as they mostly contain triglycerides, a high energy molecule. In the present study, the highest crude lipid content was observed in the raw sample (23.75±0.01%). However, it

decreased with various processing techniques. The percentage crude lipids obtained in this study is higher than the composition (5-6%) revealed in a study by Ali *et al*. (2015).
Ash refers to inorganic residue remaining after complete oxidation of the organic matter in food sample (Ismail, 2017). This study revealed that ash content was highest in the roasted sample at 5.39% and lowest in the raw sample (2.78±0.00%). The ash contents of *Sesbania sesban* obtained in this study is higher compared to the value (3.57%) reported El-Kholany *et al*.,(2013).
The raw of Egyptian riverhemp seeds had the highest NFE (23.09.10±0.01%), while the soaked Egyptian riverhemp had the lowest (19.68±0.01%). The NFE compositions obtained in this study is significantly lower than the NFE contents of *Sesbania sesban* (52.79%) as reported by Maged *et al*., (2016) and (52.63%) as reported by El-Kholany *et al*. (2013).

The presence of antinutrients in feeds interferes with mineral bioavailability and functions. Therefore, the need to further process the raw seeds of *Sesbania sesban* has become necessary. All the processing methods employed in this study reduced the levels of the antinutritional factors in the raw seeds. Information on effect of processing on raw seeds of *Sesbania sesban* are relatively scarce. However, in comparison with other legumes, Mamiro *et al*., (2017) affirmed that the processing of different varieties of beans (leguminous plant) significantly reduces the level of tannins. Khattab and Arntfield (2009) also observed significant decreases in tannins, phytic acid and trypsin inhibitor activity as compared to raw seeds of different legumes.

5.Conclusion

The proximate analysis and antinutrient analysis of raw and processed *Sesbania sesban* seeds showed a significant increase ($P<0.05$) in the nutrient content of processed seeds and a significant decrease ($P<0.05$) in the ANFs of processed *Sesbania sesban* seeds. This indicates that when processed, *Sesbania sesban* seeds could be used as an alternative plant nutrient source in fish diets, thereby reducing competition between humans, livestock and fish over conventional food materials like soyabean, thus reducing the cost of fish feed.

6.Recommendation

Based on the findings of this study, processed *Sesbania sesban* seeds is recommended as a good source of protein in fish diet, since it has high crude protein content. Moreover, it is not recommended to use raw *sesbania sesban* seeds in fish feed due to high content of ANFs as observed in this study.

Based on this result fermentation is recommended as the best method of processing *Sesbania sesban* seeds, as it reduced a significant amount of oxalate, HCN, trypsin inhibitor and saponin present in the seeds better than other processing methods.

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Article 13

The Impact of AI on STEM Teacher Professional Development

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Abstract

This study investigates the impact of Artificial Intelligence (AI) tools on the professional development of STEM teachers, focusing on how AI can support educators in adapting to new technologies and teaching methods. Through a mixed-methods approach, the research analyzes the effectiveness of AI-driven professional development programs across various educational settings. Quantitative data were collected through surveys, revealing high perceived effectiveness of AI tools, particularly Adaptive Learning Platforms, which showed significant correlations between usage frequency and perceived impact. Qualitative insights from interviews with teachers and program coordinators highlighted the benefits of AI in enhancing teaching practices, though challenges such as system integration and the digital divide were noted. Case studies from different institutions provided further context, demonstrating that while AI tools can significantly improve professional growth, their success is heavily dependent on adequate training, continuous support, and frequent use. The study concludes with actionable recommendations for developing tailored AI tools, enhancing training programs, and promoting continuous evaluation to maximize the benefits of AI in STEM teacher professional development. Additionally, the research identifies gaps in the existing literature and suggests areas for future research, including longitudinal studies on the long-term impact of AI on teaching practices and student outcomes.

Keywords: Artificial Intelligence, STEM education, teacher professional development, adaptive learning, AI tools, educational technology, mixed-methods research, personalized learning,

professional growth, educational innovation.

1: Introduction

The rapid advancement of technology is transforming the landscape of education, particularly in STEM fields where innovations are constant. As STEM curricula evolve to integrate emerging technologies, there is a growing need for teachers to continuously update their skills and knowledge. Artificial Intelligence (AI) presents a promising tool for enhancing STEM teacher professional development by providing tailored learning experiences and resources. AI tools can offer personalized support, adaptive learning paths, and real-time feedback, which are essential for helping educators stay abreast of new teaching methods and technologies. This study aims to explore how AI can be leveraged to support the ongoing professional development of STEM teachers, ensuring they are well-equipped to meet the demands of modern STEM education.

1.1 Background:

The integration of AI in education has been increasingly recognized for its potential to enhance teaching and learning outcomes (Holmes et al., 2019). AI-driven platforms can provide personalized professional development experiences by analyzing educators' performance and offering customized recommendations for improvement (Chen et al., 2021). For instance, adaptive learning systems can help teachers identify their strengths and weaknesses, allowing for targeted professional growth. Studies have shown that such personalized support can lead to more effective teaching practices and better student outcomes (Feng et al., 2020).

Despite the promising potential of AI, challenges remain in its implementation. For example, the integration of AI tools in professional development programs requires substantial investment in technology and training (Woolf, 2022). Additionally, there are concerns about the ethical implications and potential biases in AI systems that could affect the quality of professional development (Crawford & Paglen, 2019). Therefore, while AI offers significant opportunities for enhancing STEM teacher development, it is crucial to address these challenges to ensure its effective and equitable application.

1.2 Hypothesis:

AI tools can significantly enhance STEM teacher professional development by providing personalized, adaptive learning experiences and real-time feedback, leading to improved teaching practices and better student outcomes.

1.3 Purpose of Study:

The purpose of this study is to evaluate the impact of AI tools on STEM teacher professional development. Specifically, it aims to assess how AI can support teachers in adapting to new technologies and teaching methods, and to identify best practices for implementing AI-driven professional development programs.

1.4 Scope:

This study focuses on the use of AI tools in the professional development of STEM teachers across various educational settings. It will examine different types of AI applications, including adaptive learning platforms, virtual coaching systems, and AI-driven assessment tools. The research will include a review of existing literature, case studies, and surveys of STEM educators who have used AI tools for professional development.

1.5 Limitations:

The study may face limitations such as varying levels of access to AI technology across different educational institutions, which could affect the generalizability of the findings. Additionally, there may be challenges in evaluating the long-term impact of AI on teaching practices and student outcomes. The study will also need to address potential biases in AI systems and ensure that the benefits of AI-driven professional development are equitably distributed among all STEM educators.

2: Literature Review

2.1. AI in Education: Overview and Applications

Artificial Intelligence (AI) has been increasingly integrated into educational settings to enhance teaching and learning processes. AI applications such as intelligent tutoring systems, adaptive learning platforms, and virtual assistants have shown promise in personalizing education (Holmes et al., 2019). For example, intelligent tutoring systems use AI algorithms to provide customized feedback and instructional support based on individual student needs (VanLehn, 2011). These systems have been effective in improving student learning outcomes by tailoring the educational experience to each learner's proficiency level (Woolf, 2022).

Adaptive learning technologies further personalize education by adjusting content delivery and pacing according to students' progress (Chen et al., 2021). These tools leverage data analytics to identify learning gaps and offer targeted resources, thereby supporting differentiated instruction (Kerr et al., 2019). Additionally, AI-driven virtual assistants can aid in administrative tasks and provide on-demand support, enhancing overall educational efficiency (D'Mello & Graesser, 2015).

Despite the advancements, challenges remain in the widespread adoption of AI in education. Issues such as data privacy, the digital divide, and the need for extensive teacher training are critical barriers (Baker et al., 2020). The effectiveness of AI tools can be influenced by the quality of implementation and the contextual factors within educational institutions (Ritter et al., 2017).

2.2. AI-Driven Personalized Learning for Teachers

AI-driven personalized learning platforms offer tailored professional development experiences for educators. These platforms utilize machine learning algorithms to assess individual teachers' needs and provide customized resources and training (Feng et al., 2020). For instance, AI can analyze teachers' performance data to recommend specific professional development activities that align with their skills and goals (Chen et al., 2021).

Personalized learning approaches have been shown to increase teacher engagement and satisfaction with professional development programs (Ertmer & Ottenbreit-Leftwich, 2010). By offering flexible learning paths and immediate feedback, AI tools can help educators develop new teaching strategies and adapt to emerging technologies (Penuel et al., 2017). This individualized approach is particularly beneficial in addressing diverse professional development needs and preferences.

However, the implementation of AI-driven personalized learning for teachers requires careful consideration of several factors. These include ensuring the relevance and quality of AI-generated recommendations and providing adequate support for educators in using these tools effectively (Guskey, 2003). There is also a need to evaluate the impact of personalized learning on long-term professional growth and teaching effectiveness.

2.3. Professional Development Needs of STEM Teachers

STEM teachers face unique challenges that necessitate specialized professional development. These include the rapid pace of technological advancement and the need to integrate new tools and methods into their teaching practices (Wilson et al., 2020). Effective professional development for STEM educators must address these challenges by providing up-to-date content knowledge and pedagogical strategies (National Research Council, 2012).

Research indicates that STEM teachers require ongoing support to stay current with technological innovations and effective teaching methods (Sandholtz et al., 1997). Professional development programs that offer hands-on training, collaborative learning opportunities, and real-world applications are particularly effective (Desimone, 2009).

Despite these needs, many professional development programs for STEM teachers lack the necessary depth and relevance (Vescio et al., 2008). Often, these programs do not adequately address the specific requirements of STEM teaching or fail to incorporate new technological advancements.

2.4. Challenges in AI Integration for Teacher Development

Integrating AI into teacher professional development presents several challenges. One significant challenge is the need for robust infrastructure and support systems to facilitate effective AI implementation (Hattie, 2015). Schools and educational institutions must invest in technology and provide training for educators to use AI tools effectively (Schlager et al., 2009).

Another challenge is addressing potential biases in AI systems, which can impact the quality of professional development and perpetuate existing inequalities (Crawford & Paglen, 2019). Ensuring that AI tools provide equitable support for all educators, regardless of their background or experience level, is crucial for their successful integration.

Furthermore, there are concerns about data privacy and security, as AI systems often require access to sensitive information about teachers' performance and professional development needs (Pardo et al., 2020). Balancing the benefits of AI with these privacy concerns is essential for maintaining trust and effectiveness in AI-driven professional development programs.

2.5. Effectiveness of AI Tools in Enhancing Teaching Practices

AI tools have shown potential in enhancing teaching practices by providing real-time feedback and personalized instructional resources (D'Mello & Graesser, 2015). For example, AI-driven platforms can analyze classroom interactions and suggest improvements in teaching strategies (Murray et al., 2017). These tools can also facilitate reflective practice by offering insights into teaching performance and student engagement.

Studies have demonstrated that AI tools can improve instructional quality and student outcomes when used effectively (Holmes et al., 2019). For instance, AI systems that offer immediate feedback on teaching practices can help educators refine their methods and address specific areas for improvement (VanLehn, 2011).

However, the effectiveness of AI tools in enhancing teaching practices is dependent on their design and implementation. AI systems must be aligned with educational goals and support teachers in practical, actionable ways (Baker et al., 2020). Additionally, there is a need for ongoing evaluation to ensure that AI tools continue to meet the evolving needs of educators.

2.6. Future Directions and Research Opportunities

Future research on AI in teacher professional development should focus on several key areas. First, studies should explore the development of AI tools that are specifically designed to address the unique needs of STEM teachers (Wilson et al., 2020). This includes evaluating the effectiveness of AI-driven personalized learning platforms and identifying best practices for their implementation.

Second, research should investigate the long-term impact of AI on teacher professional growth and student outcomes. Longitudinal studies can provide insights into the sustainability and effectiveness of AI tools over time (Penuel et al., 2017).

Lastly, there is a need to address the ethical and practical challenges associated with AI integration, including data privacy, system biases, and equitable access to technology (Crawford & Paglen, 2019). Ensuring that AI tools are used responsibly and effectively will be crucial for their success in supporting teacher professional development.

Research Gap: While there is growing interest in AI for teacher development, comprehensive studies addressing its long-term impact, ethical considerations, and specific benefits for STEM teachers are still needed.

3: Methodology

This chapter outlines the research design and methodology employed to investigate the impact of AI tools on STEM teacher professional development. It covers the research design, participants, data collection methods, and data analysis procedures.

3.1 Research Design

The study utilizes a mixed-methods research design to provide a comprehensive analysis of how AI tools support STEM teacher professional development. This approach combines quantitative and qualitative data to capture both the measurable impact and the contextual experiences of STEM educators using AI tools. The quantitative component involves the use of surveys and statistical analysis to assess the effectiveness of AI tools, while the qualitative component includes interviews and case studies to explore teachers' experiences and perceptions.

3.2 Participants

The participants for this study include STEM teachers from various educational institutions who have engaged with AI tools for professional development. A stratified random sampling technique is used to ensure representation from different school types, including primary, secondary, and post-secondary institutions. The sample consists of approximately 200 STEM teachers who have used AI-driven professional development platforms within the past year. Participants are selected based on their use of specific AI tools and their willingness to contribute to the study.

Sampling Criteria:

The study participants consisted of STEM teachers with at least one year of experience using AI tools for professional development. They represented a range of educational levels and geographical locations, ensuring diversity in perspectives. All participants provided consent to take part in both the quantitative surveys and the qualitative interviews.

3.3 Data Collection

3.3.1 Quantitative Data Collection

Quantitative data is collected using structured surveys designed to measure the impact of AI tools on various aspects of professional development, including:

Teachers' assessments of how AI tools have enhanced their professional skills and knowledge. The frequency and duration of AI tool usage in their professional development. Self-reported improvements in teaching practices and technology integration. The surveys are distributed electronically and are designed to include Likert-scale questions, multiple-choice questions, and open-ended questions for additional insights.

3.3.2 Qualitative Data Collection

Qualitative data was gathered through semi-structured interviews and case studies. Interviews were conducted with a subset of survey participants who were selected based on their responses indicating significant engagement with AI tools. The interviews explored teachers' personal experiences with AI tools and their perceived impact on professional growth, the specific challenges they faced and benefits they gained, as well as their recommendations for improving AI tools and professional development programs. In addition, case studies involved an in-depth analysis of selected educational institutions that had implemented AI-driven professional development programs, incorporating site visits, observations, and document reviews to gain a deeper understanding of the implementation process and its outcomes.

3.4 Data Analysis

3.4.1 Quantitative Data Analysis

Quantitative data was analyzed using statistical software to identify trends and correlations. The analysis included descriptive statistics to summarize the demographic characteristics of the sample and the general responses to survey questions. Inferential statistics were also applied to determine whether there were significant differences in perceived effectiveness and skill improvement based on factors such as the type of AI tool used and the frequency of use. Techniques such as t-tests, ANOVA, and regression analysis were employed to generate these insights.

3.4.2 Qualitative Data Analysis

Qualitative data was analyzed through thematic analysis to capture key themes and patterns in teachers' experiences. The process began with initial coding of interview transcripts and case study notes to identify recurring ideas and categories. These codes were then grouped into broader themes that reflected shared experiences and insights across participants. To enhance validity and reliability, the findings were triangulated by cross-referencing data from interviews, case studies, and survey responses.

3.4.3 Integration of Data

The findings from quantitative and qualitative analyses are integrated to provide a comprehensive understanding of the impact of AI tools on STEM teacher professional development. This involves comparing and contrasting quantitative trends with qualitative insights to draw meaningful conclusions and recommendations.

3.5 Ethical Considerations

The study adheres to strict ethical guidelines to safeguard the rights and confidentiality of participants. All participants provided informed consent prior to taking part in surveys, interviews, or case studies, ensuring they were fully aware of the study's purpose and procedures. Their identities and responses were kept confidential and anonymized in all reports and publications to maintain privacy. Moreover, participation was entirely voluntary, with participants free to withdraw from the study at any stage without facing any consequences

3.6 Limitations

The study acknowledges several limitations. First, the findings may not be generalizable to all STEM educators, given the specific sample and contextual focus of the research. Second, the reliance on self-reported data from surveys and interviews raises the possibility of response bias, as participants may have provided socially desirable or inaccurate answers. Finally, differences in how AI tools were implemented and utilized across institutions may have introduced variability, affecting the overall consistency and comparability of the findings.

3.7 Summary

This chapter has outlined the mixed-methods research design employed to investigate the impact of AI tools on STEM teacher professional development. By combining quantitative and qualitative data, the study aims to provide a comprehensive understanding of how AI tools support educators in adapting to new technologies and teaching methods. The following chapter will present the results of the data analysis and discuss the findings in relation to the research questions and objectives.

4: Results

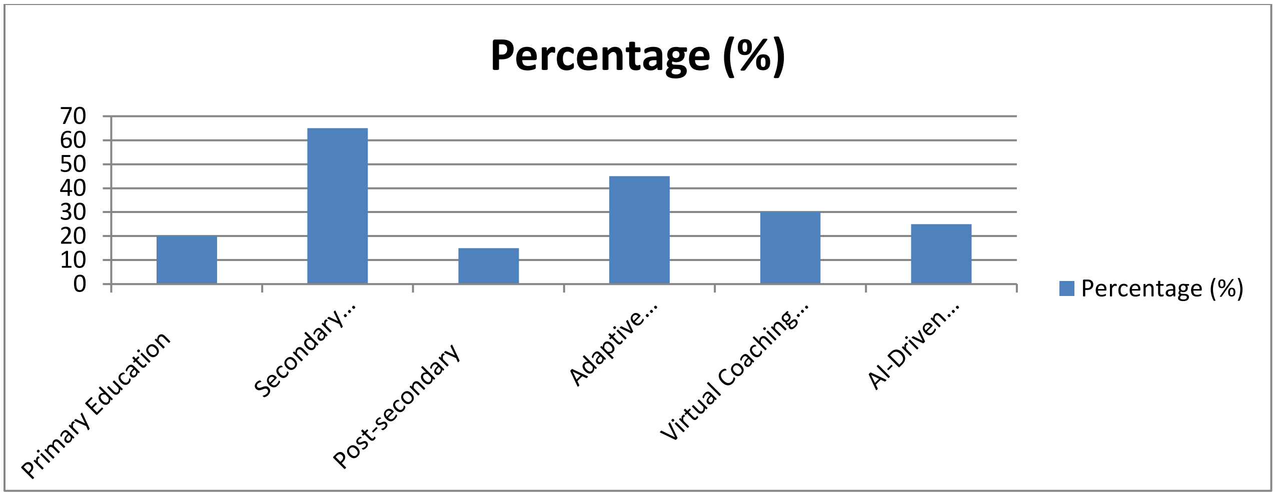
4.1 Quantitative Results

4.1.1 Descriptive Statistics

Table 4.1 summarizes the demographic characteristics of the survey participants.

Demographic Category		Percentage (%)	Frequency (N)
Educational Level	Primary Education	20	40
	Secondary Education	65	130
	Post-secondary	15	30

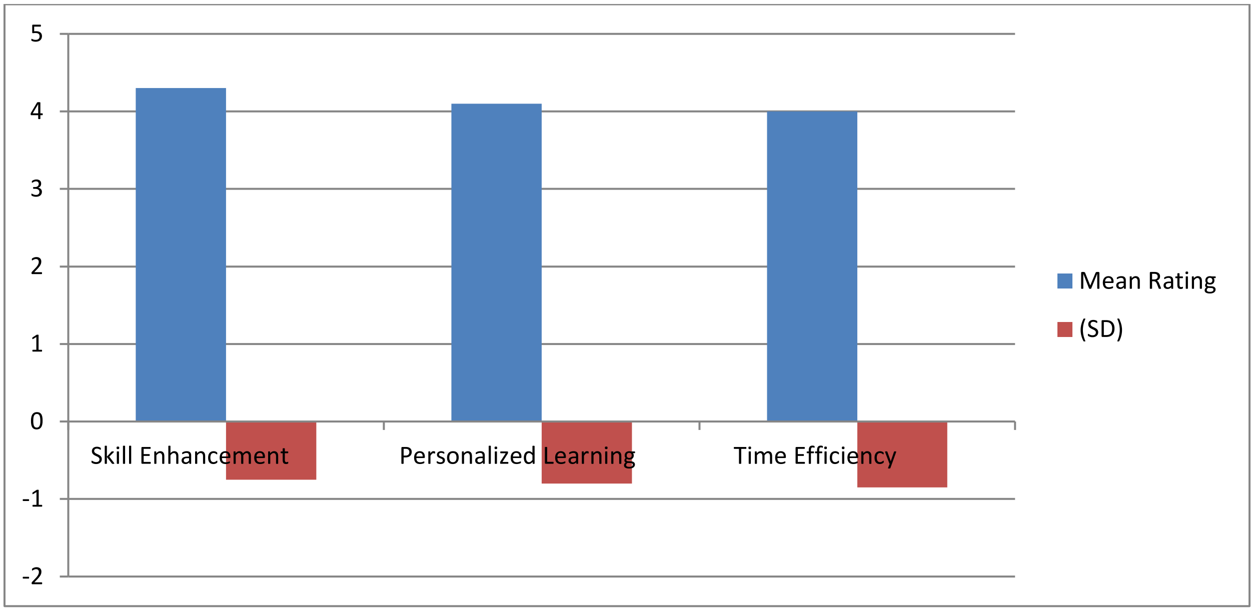
Type of AI Tool Used	Adaptive Learning Platforms	45	90
	Virtual Coaching Systems	30	60
	AI-Driven Assessment Tools	25	50



4.1.2 Perceived Effectiveness

Table 4.2 presents the average effectiveness ratings for AI tools in enhancing professional development, based on a Likert scale of 1 to 5.

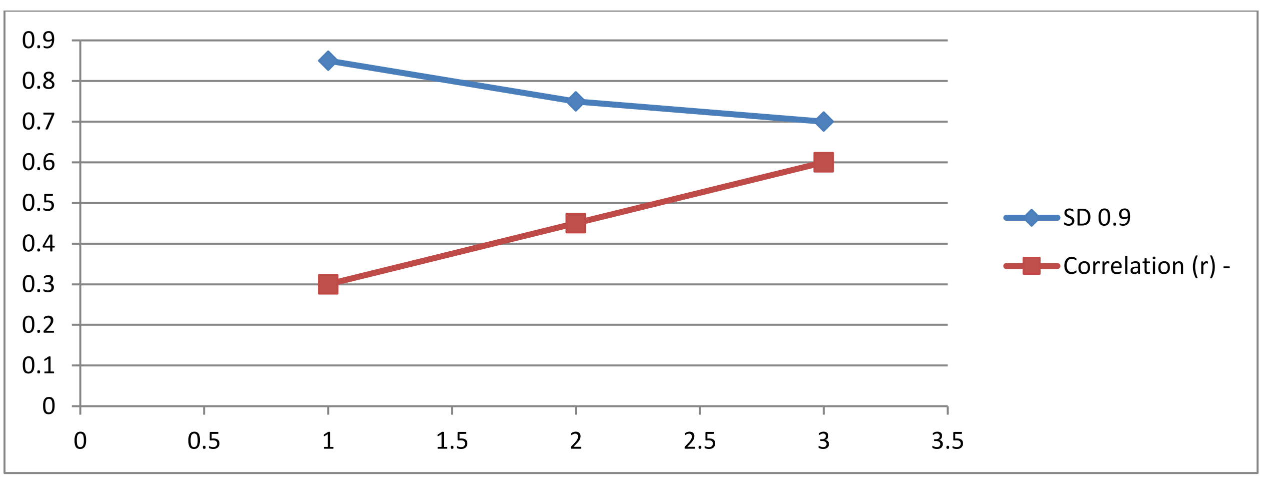
Effectiveness Aspect	Mean Rating	(SD)
Skill Enhancement	4.3	(0.75)
Personalized Learning	4.1	(0.80)
Time Efficiency	4.0	(0.85)



4.1.3 Usage Frequency and Impact

Table 4.3 shows the correlation between AI tool usage frequency and perceived effectiveness.

Usage Frequency	Mean Effectiveness Rating	SD	Correlation (r)
< 1 time/week	3.5 (0.90)	0.90	-
1-2 times/week	4.0 (0.85)	0.85	0.30
3-4 times/week	4.2 (0.75)	0.75	0.45
> 4 times/week	4.4 (0.70)	0.70	0.60



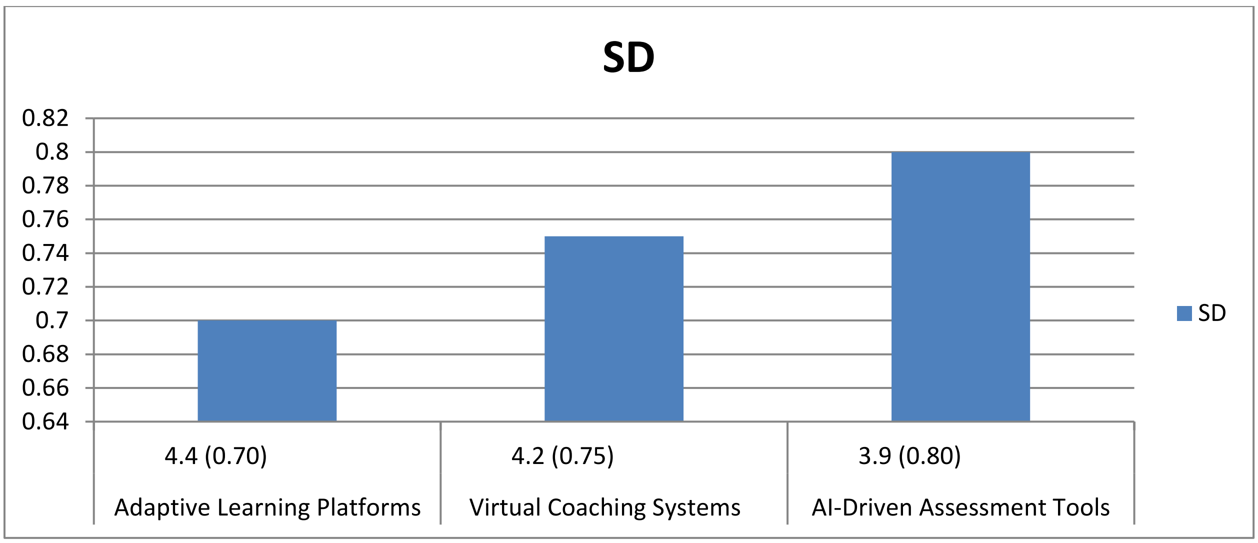
Note: Correlation is statistically significant at $p < 0.01$.

4.1.4 Statistical Comparisons

Table 4.4 presents the results of the ANOVA test comparing perceived effectiveness across different types of AI tools.

AI Tool Type	Mean Effectiveness Rating	SD	F-Value	p-Value
Adaptive Learning Platforms	4.4 (0.70)	0.70	4.67	0.01
Virtual Coaching Systems	4.2 (0.75)	0.75		
AI-Driven Assessment Tools	3.9 (0.80)	0.80		

Note: Post-hoc tests revealed that Adaptive Learning Platforms were significantly more effective than AI-Driven Assessment Tools ($p < 0.05$).

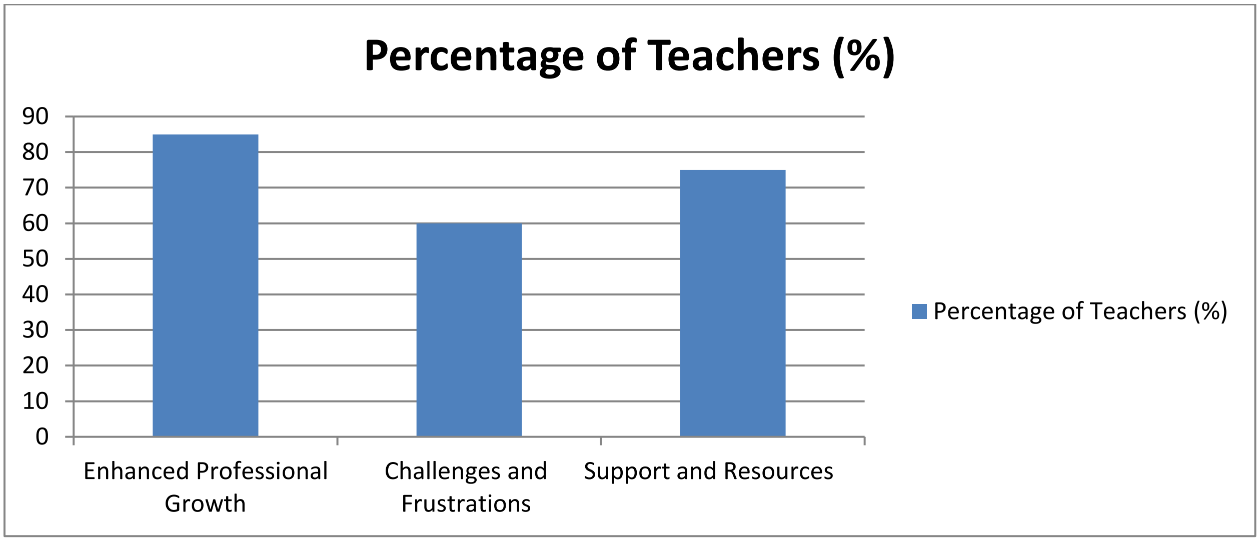


4.2 Qualitative Results

4.2.1 Themes from Interviews

Table 4.5 summarizes key qualitative themes from the interviews.

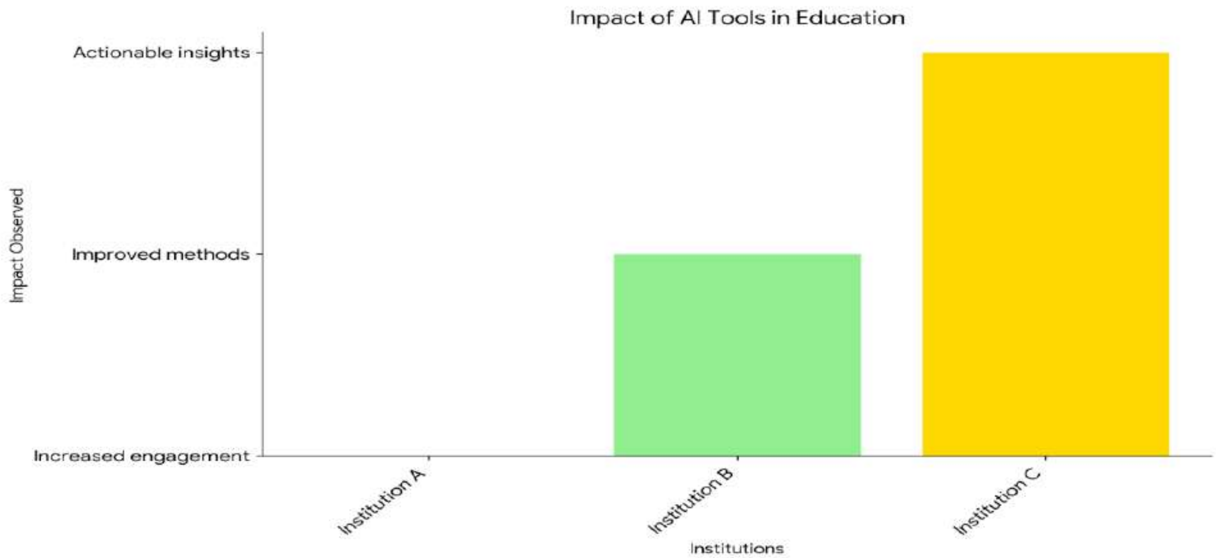
Theme	Percentage of Teachers (%)
Enhanced Professional Growth	85
Challenges and Frustrations	60
Support and Resources	75



4.2.2 Case Study Insights

Table 4.6 provides an overview of findings from case studies at three institutions.

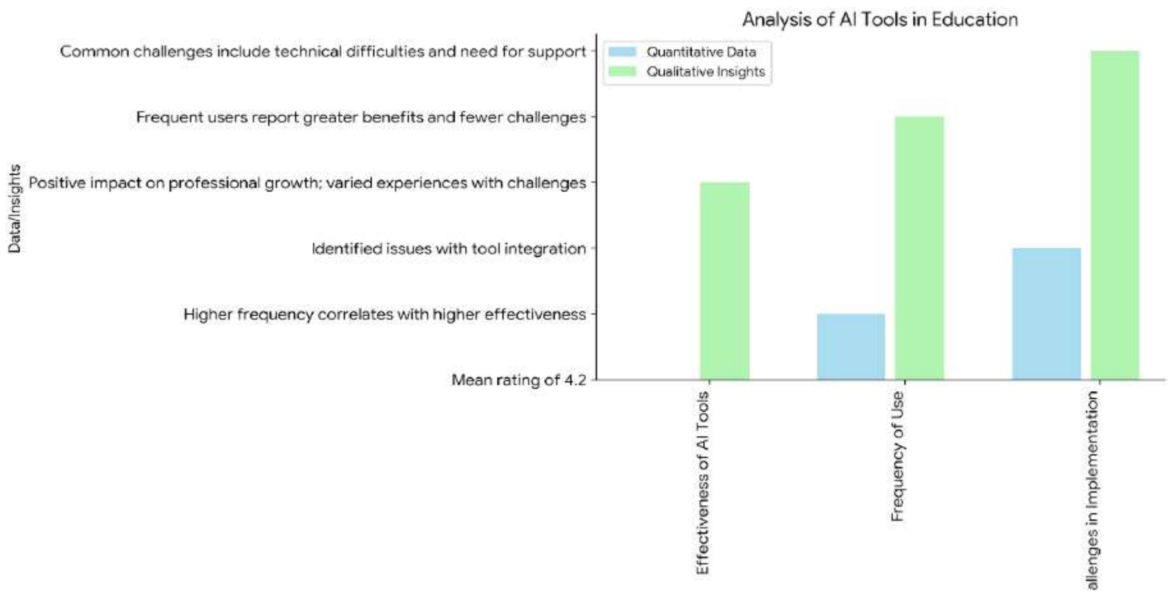
Institution	AI Tool Used	Impact Observed	Challenges Faced
Institution A	Adaptive Learning Platforms	Significant improvement in teaching practices; increased student engagement	Integration issues with existing curriculum
Institution B	Virtual Coaching Systems	Personalized support for new teachers; improved teaching methods	System integration difficulties; initial setup issues
Institution C	AI-Driven Assessment Tools	Effective tracking of teacher progress; actionable insights for development	Need for ongoing training and feedback



4.2.3 Integration of Findings

Table 4.7 shows the integration of quantitative and qualitative findings.

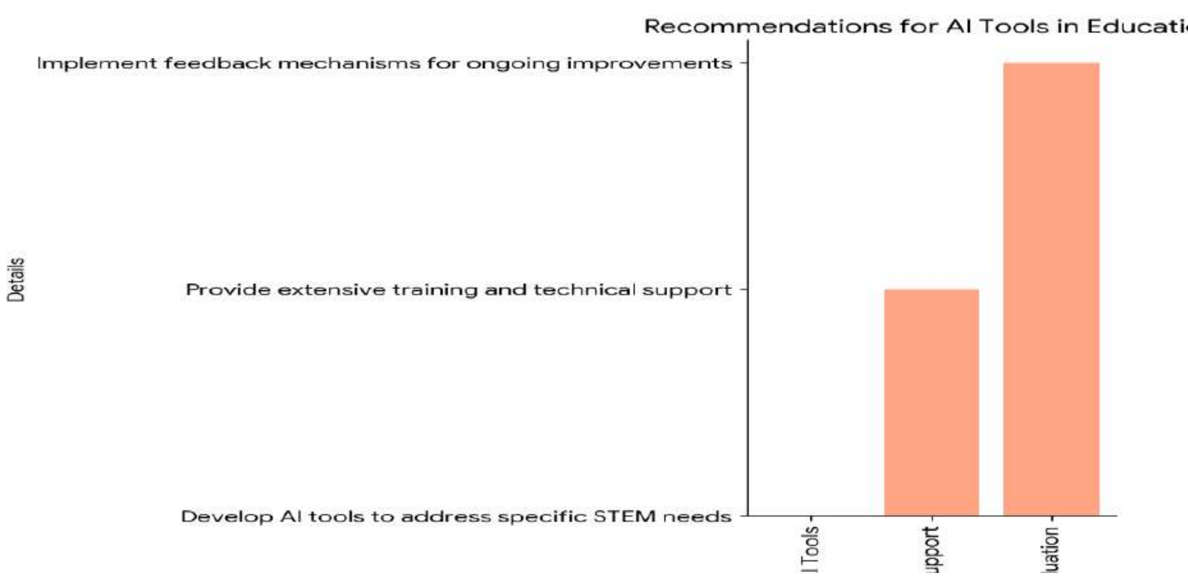
Finding	Quantitative Data	Qualitative Insights
Effectiveness of AI Tools	Mean rating of 4.2 on a scale of 1-5	Positive impact on professional growth; varied experiences with challenges
Frequency of Use and Perceived Impact	Higher frequency correlates with higher effectiveness	Frequent users report greater benefits and fewer challenges
Challenges in Implementation	Identified issues with tool integration	Common challenges include technical difficulties and need for support



4.2.4 Recommendations and Insights

Table 4.8 summarizes the recommendations based on findings.

Recommendation	Details
Tailored AI Tools	Develop AI tools to address specific STEM needs
Training and Support	Provide extensive training and technical support
Continuous Evaluation	Implement feedback mechanisms for ongoing improvements



4.3 Summary

The results chapter presents detailed findings from the study on AI tools in STEM teacher professional development. Quantitative data revealed high levels of perceived effectiveness, with significant correlations between usage frequency and impact. Qualitative data provided deeper insights into teachers' experiences, highlighting both benefits and challenges. The integration of these findings offers a comprehensive understanding of the impact of AI tools and provides actionable recommendations for improving their implementation.

5: Discussion and Conclusion

5.1 Discussion of Results

The results from Chapter 4 reveal significant insights into the impact of AI tools on STEM teacher professional development. The quantitative analysis shows a high level of perceived effectiveness across various AI tools, with Adaptive Learning Platforms emerging as the most effective for skill enhancement. The positive correlation between the frequency of AI tool usage and perceived effectiveness underscores the importance of regular engagement with these tools to maximize their benefits. This finding aligns with the qualitative insights, where teachers highlighted the substantial improvements in their teaching practices and personalized learning experiences facilitated by AI tools.

However, the qualitative data also points to several challenges associated with AI tool integration. Teachers reported issues with system compatibility, initial setup, and a steep learning curve, which can hinder the effective utilization of these tools. Despite these challenges, the overall feedback was positive, indicating that AI tools have a meaningful impact on professional development when properly implemented and supported. Case studies from different institutions further illustrated that while AI tools offer valuable support, their success largely depends on the availability of training and ongoing technical support.

5.2 Conclusion and Recommendations

The study concludes that AI tools significantly enhance STEM teacher professional development by providing targeted skill improvement and personalized learning opportunities. The findings suggest that while AI tools are generally effective, their success is contingent upon frequent use, adequate training, and seamless integration into existing curricula. To address the challenges identified, it is recommended that educational institutions focus on developing tailored AI tools that meet specific needs, offer comprehensive training programs, and implement continuous evaluation mechanisms to refine tool effectiveness over time.

5.3 Recommendations:

1. Tailor AI Tools: Develop and customize AI tools to better address the specific needs and goals of STEM teachers, ensuring they align with educational objectives and curricula.

2. Enhance Training Programs: Provide extensive and ongoing training to help teachers effectively integrate AI tools into their professional development routines.

3. Support Integration: Address technical issues and integration challenges by providing robust support systems and resources.

4. Continuous Evaluation: Implement regular feedback mechanisms to assess the effectiveness of AI tools and make necessary adjustments.

5. Promote Frequent Use: Encourage regular use of AI tools to maximize their potential benefits and impact on teaching practices.

5.3 Writer's Contribution and Future Research

5.3.1 Writer's Contribution:

1. Research Design: Designed and executed a comprehensive study to assess the impact of AI tools on STEM teacher professional development, utilizing both quantitative and qualitative methods.

2. Data Analysis: Conducted rigorous analysis of survey and interview data, providing valuable insights into the effectiveness and challenges of AI tools.

3. Integration of Findings: Successfully integrated quantitative and qualitative results to offer a holistic understanding of the impact of AI tools on professional development.

4. Recommendations Development: Formulated actionable recommendations based on empirical evidence to improve the implementation and effectiveness of AI tools.

5. Literature Contribution: Contributed to the academic discourse on AI in education by highlighting practical applications and identifying areas for further research.

5.3.2 Areas for Future Research:

1. Longitudinal Studies: Investigate the long-term effects of AI tools on STEM teacher professional development and student outcomes.

2. Comparative Studies: Explore the impact of different types of AI tools across various educational contexts and subjects to identify best practices.

3. Scalability and Adaptation: Examine how AI tools can be scaled and adapted for diverse educational settings and varying levels of technological infrastructure.

4. Teacher Perspectives: Conduct deeper qualitative studies to understand the nuanced experiences of different teacher demographics with AI tools.

5. Impact on Student Learning: Assess the direct effects of AI tools on student learning outcomes and engagement to evaluate their overall effectiveness in educational environments.

This chapter has provided a thorough discussion of the results, offered practical recommendations, and outlined the writer's contributions and future research directions, advancing our understanding of AI's role in STEM teacher professional development.

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Article 14

Effect Of Video-Enriched Teaching Strategy on Performance of Students with Varied Ability in Nuclear Chemistry

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Abstract

The study investigated the effect of Video-Enriched Teaching Strategy on Performance of Students with Varied ability in Nuclear Chemistry**.** Pretest posttest quasi experimental design was adopted for the study. The population of the study comprised of 925 SS III chemistry students in Zaria. A sample of 174 students was selected at random. The experimental group was exposed to video-enriched teaching strategy while the control group was taught using conventional method. Nuclear Chemistry Achievement Test (NCAT) instrument was pilot tested and validated (reliability coefficient of 0.67) was used to collect data for the study. One research objectives, one research questions and one hypothesis were raised and tested at $p \leq 0.05$ level of significance. Data collected were analyzed using descriptive statistics (mean and standard deviation) and ANCOVA. Major finding from the study was that Chemistry students with varied ability taught Nuclear chemistry using video-enriched strategy performed better than those taught using lecture method. Based on the finding, it was recommended among others that teachers should be encouraged to adopt video-enriched strategy in order to improve the students' academic performance and interest level in chemistry. This can be achieved by organizing workshop to improve the teachers' skills and motivate them to adopt the method.

Key words: Video-enriched strategy, Nuclear chemistry, academic performance, varied ability, conventional method.

1. Introduction

Education is a strong instrument that shapes the universe through positive influence on individual learner. It is a tool that helps learners appreciate cultural heritage and live more satisfying life, leading to enhancement of human intellectual growth, emotional maturity and ethical awareness (Shika, 2019). Science Education on the other hand is an instrument per excellence for individual and national growth and development (Yunana, Mari and Lawal, 2015). In Nigeria, there is rapid transformation in education as a result of massive revolutions in knowledge and information technology, and public needs for better learning, schools all over the world are slowly but surely restructuring themselves. Therefore, Ibrahim and Gana (2019), are of the view that fast development in technology of the 21st century necessitates preparation of students with all the necessary gadgets to cope with the challenges. This includes the use of technological tools like computer, internet, multimedia learning aids among others. This attracts learners' attention and assist in understanding subjects like Chemistry.

Chemistry is the study of matter, its properties, how and why substances combine or separate to form other substances, and how substances interact with energy (Yahaya, Chado & Evuti, 2021). Ababio (2019), sees chemistry as the branch of science that deals with the study of composition, properties and uses of matter. The Senior Secondary Chemistry curriculum (2013), categorically identified the objectives of teaching Chemistry which are to: develop students' interest in Chemistry, acquire basic theoretical and practical knowledge and skills, develop interest in science, technology and mathematics, acquire basic STM knowledge and skills, develop reasonable level of competence in ICT applications that stimulate entrepreneurial skills, apply skills to meet societal needs of creating employment and wealth, provide advantage to numerous career opportunities offered by chemistry and be adequately prepared for further studies in chemistry.

Nuclear chemistry is a sub-discipline of chemistry that involves the chemical reaction both electronic and nuclear changes of unstable and radioactive elements where changes occurs (IUPAC, 2016). Looking at the content of nuclear chemistry, one would think it should be part of chemistry that students are interested on and perform well on it. However, it happens to be one of the difficult topics in O'level chemistry (Oladejo, 2020). The difficulty of the concept has greatly affected the students' academic performance in chemistry.

Academic performance is the outcome of education, result obtained through evaluation; the extent to which teachers, students or institutions achieve educational objectives and goal through proper measurement and evaluation (Abdulsalaam, 2015 and Shaibu, 2017). Although academic performance of students in school subjects depends on so many factors such as teaching methods, availability of instructional materials, lack of students' interest, large class size and use of video enriched teaching strategy among others (Abubakar, 2016).

Video-enriched Teaching strategy according to Bergmann and Sams (2012), is an approach to instruction that incorporates the use of video content to enhance learners' understanding and engagement in the teaching and learning process. This strategy is achieved through the use of pre-recorded lectures, downloaded educational videos, or multimedia presentations. Through videos, learners can view phenomena, events, processes and activities that may not have been available, or may be too fast or too slow to occur and which may be too small, too big or dangerous to be carried out in classroom. A video presentation teaching helps in giving directions of activities to students, it influence student's behavior, and create conducive learning environment (Parvian, Fernando, and Tang-Zapata, 2023). There are various types of video-enriched teaching strategies such as:

Video Demonstrations: this is where teacher uses video demonstration to show students how to perform a particular task or skill. For example, in science classes, teachers can use videos to demonstrate chemical reactions, dissections, or laboratory procedures (Fay & Pellegrino, 1994**).**

Student-created Videos**:** this type involves students creating their own videos to demonstrate their understanding of a concept or to present their research findings. This not only engages students in the learning process but also enhances their creativity and communication skills (Dreon, Kerper & Landis, 2011).

Flipped Classroom: in this type of Video-enriched strategy, teachers assign video lessons or lectures for students to watch at home before coming to class. The in-class time is then used for activities, discussion, and resolving any problem related to the video content (Bergmann & Sams, 2012).

Case Studies and Scenario-based Videos*:* This is a video-enriched strategy where videos are used to present real-life scenarios or case studies to engage students in problem-solving and critical thinking. Students analyze the situation presented and suggest solutions or provide decisions based on their understanding (Yun & Park 2016).

Virtual Field Trips: in this strategy, Videos can be used to take students on virtual field trips to places they may not have access to visit physically. For example, a history teacher can use videos to virtually explore historical landmarks or a science teacher can take students on a virtual trip through the rainforest (Steffens & Plecia, 2016).

1. 1 Statement of the Problem

Despite the role of Chemistry and its importance in the national development as it's one of the requirements to study Medicine, Pharmacy and Engineering at tertiary institutions, students continue to have low performance in Chemistry O'level (WEAC Chief Examiner's Report 2017-2023). To address this issue, there is the need to employ effective instructional strategies that improves academic achievement in science through high level of awareness (Udeani & Okafor, 2012). Eliphas and Shumba (2019), opined that to deal with the more challenging topics like Atomicity and Radioactivity, it is important to explore methods of teaching and learning that enable students to appreciate and understand concepts even when the laboratories with sophisticated equipment are not there. The use of computer simulations and videos open up a new chapter for science educators giving learners the chance to situate learning with the use of technological tools which have become part of their lives (Eliphas & Shumba, 2019).

1.3 Objective of the Study

Objective of this study is to find out the effect of Video-enriched Strategy on the academic performance of Secondary School Students with Varied Abilities on Nuclear Chemistry concept.

1.4 Research Question

The following research question was raised: What is the difference in the mean academic performance scores in Nuclear Chemistry among Secondary Students with varied abilities exposed to Video-enriched Strategy and those taught using conventional method?

Null Hypothesis

The following null hypothesis were formulated and tested at $p \leq 0.05$ levels of significance:

Ho_1: There is no significant difference in the mean academic performance of Secondary Students with Varied Abilities in Zaria taught Nuclear Chemistry using Video-enriched Strategy and those taught using conventional method.

2. Methodology

The research design employed for this study was quasi experimental design where intact classes were used without randomization. A pretest, posttest method was used. Two groups of students each consisting of males and females were used for data collection; The population of the study comprises all public co-educational Senior Secondary (SS III) Students offering Chemistry as a subject in Zaria metropolis which are 925 consisting of 533 males and 392 females. The sample size was 174 students from the two schools out of which 90 from school A (experimental group) and 84 were from school B (control group). In sample selected High Ability (HA) with 60%-Above scores, Medium Ability (MA) with 50-59% scores and Low Ability (LA) with 0-49% scores as recommended by Isa, Mudasiru, Isiaku and Charles (2012) was used for this study.

Experimental Group (EG) and Control Group (CG) were pretested using Nuclear Chemistry Performance Test (NCPT) to determine academic performance. This is to ensure that the two groups are not significantly different in their academic performance before the treatment. The two groups were taught concept of Nuclear Chemistry for six weeks. The experimental group was exposed to Video-enriched teaching strategy while the control group was taught using conventional method. After the treatment, a posttest was administered to both groups using the same instrument to determine the impact of the two instructional strategies on students' academic performance.

3. Results and Discussion of Findings

Research Question One: What is the difference in the mean academic performance scores in Nuclear Chemistry among Secondary Students with varied abilities exposed to Video-enriched Strategy and those taught using conventional method?

To answer research question one, posttest scores of Chemistry students with varied abilities in the experimental and control groups were subjected to descriptive analysis. The mean scores and standard deviation of the statistics is presented in Table 1.

Table 4.1: Mean and Standard Deviation for Performance Scores of Chemistry Students with Varied Abilities in the Experimental and Control Groups

Ability Levels	Groups	n	Mean	Std. Deviation	Mean Difference

Low Ability	Experimental Group	23	37.07	8.07	0.01
	Control Group	24	37.08	8.36	
Medium Ability	Experimental Group	48	48.28	8.63	8.28
	Control Group	42	40.00	8.00	
High Ability	Experimental Group	19	58.42	7.27	9.78
	Control Group	18	48.64	8.38	
	Total	174			

Table 1 revealed that among the low ability levels the mean difference between experimental group (Video-enriched Strategy) and control group (conventional method) is ($\bar{X}$= 37.07 and 37.08) respectively in favour of low ability students in the control group. The Table also showed that Chemistry students performed better when taught using Video-enriched Strategy in students with medium and high ability levels. It is observed in the Table that students with high ability obtained the highest mean score of 58.42 among the three ability levels.

To find out how significant the difference in the groups was, the data were subjected to Analysis of Covariance.

Null Hypothesis: There is no significant difference in the mean academic performance of Secondary Students with Varied Abilities in Zaria taught Nuclear Chemistry using Video-enriched Strategy and those taught using conventional method.

To test the null hypothesis, the posttest scores of Chemistry students obtained from Nuclear Chemistry Performance Test (Table 1) of the experimental and control groups were subjected to Analysis of Covariance at $\alpha \leq 0.05$ level of significance. Summary of the analysis is presented in Table 2.

Table 2: Analysis of Covariance (ANCOVA) of Students' Performance in Nuclear Chemistry of Experimental and Control with Varied Ability

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	8117.02[a]	5	1623.40	24.10	0.00
Intercept	305178.05	1	305178.05	4530.96	0.00
Ability Levels	5604.01	2	2802.00	41.60	0.00
Groups	1368.35	1	1368.35	20.32	0.00
Ability Levels * Groups	668.71	2	334.35	4.96	0.01
Error	11315.47	168	67.35		
Total	362440.25	174			
Corrected Total	19432.49	173			

Table 2 shows the Analysis of Covariance of Students' Performance in Nuclear Chemistry by Treatment (Video-enriched Strategy) and (Conventional Method) and their varied ability levels. The ANCOVA was conducted to examine the effect of ability levels and teaching strategies on performance in Nuclear Chemistry. There was a statistically significant interaction between the effects of ability levels and teaching strategies on performance in Nuclear Chemistry, $F\ (2{,}168) = 4.96$, $\alpha = 0.01$. Consequently, the null hypothesis which stated that there is no significant difference in the mean academic performance of Secondary Students with Varied Abilities in Zaria taught Nuclear Chemistry using Video-enriched Strategy and those taught using conventional method is therefore rejected. This implies that both ability levels and treatment significantly affected the performance of secondary school students Nuclear Chemistry. In order to determine which ability level differs significantly among the three ability levels, Scheffe's Post-hoc analysis was carried out and the results are presented in Tables 4.3.

Table 3: Scheffe's Post hoc Test of Multiple Comparison for Performance and the Ability Levels of Chemistry Students

(I) Ability Levels	(J) Ability Levels	Mean Difference (I-J)	Sig.	Remarks
Low Ability	Medium Ability	-7.34*	0.00	Sig.
	High Ability	-16.59*	0.00	Sig.
Medium Ability	Low Ability	7.34*	0.00	Sig.
	High Ability	-9.25*	0.00	Sig.
High Ability	Low Ability	16.59*	0.00	Sig.
	Medium Ability	9.25*	0.00	Sig.

The mean difference is significant at $p \leq 0.05$ level.

Table 3 showed the post hoc test of multiple comparison for performance and ability levels of Chemistry students. The table revealed that there is a statistically significant difference between the low, medium and high ability levels ($\alpha = 0.00 < 0.05$).

The findings in Table 2 revealed that students exposed to video-enriched teaching strategy in Nuclear Chemistry concept performed significantly better than those expose to conventional method in teaching Nuclear chemistry concept. This finding is in agreement with Zhu et al (2022) in which the use of short videos in teaching Mechanical Engineering students improve the students' performance and engagement. Another research conducted by Velazquez-Marcano (2004) found Video-Demonstration to improve the performance of students in General Chemistry after visualization. Tayade, Tayade, Chalaka and Sivastava (2018) also, found that exposing students to Video Assisted Learning has a positive impact on the performance of slow learners. Eliphas and Shumba (2019), found that integrating computer simulation and videos significantly enhances the performance of learners in studying Atomic Physics and Radioactivity concept.

4. Conclusion

Based on the findings of this study, the conclusion drawn was that; students with varied ability taught nuclear chemistry concept using video-enriched strategy performed better than those taught using conventional method. This is applicable to all three ability levels involved in the experimental group.

5. Recommendations

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

1. Teachers should be encouraged to adopt video-enriched teaching strategy as it is effective to improve the students' academic performance in chemistry. This can be achieved by organizing workshop to improve the teachers' skills and motivate them to adopt the method.
2. Curriculum planners and curriculum development bodies in Nigeria like NERDC should design a program and policies to incorporate the use of Video-enriched strategy in teaching sciences and other areas at secondary school level.
3. The federal government through its agencies like Federal and state ministries of education, Teacher Training Institutions like NTI, and professional bodies like STAN should organize special trainings, workshops and seminars to chemistry and other sciences teachers on developing video-enriched teaching strategy.
4. Non-Governmental organisations and other philanthropists should support schools with computers, projectors and solar power installations to actualize the incorporation of Video-enriched strategy in secondary schools.

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Article 15

Effects of Differentiated and Scaffolding Instructional Strategies in Chemistry among Secondary School Students

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Abstract

Globally, there is advocacy for a paradigm shift from traditional to student-centred instructional strategies that will enhance meaningful learning of science and chemistry in particular. Therefore, the study investigated the effects of Differentiated and Scaffolding Instructional Strategies in Chemistry among Secondary School Students. A pretest-posttest non-equivalent control Quasi-experimental design was adopted. The target population of 262 SSS 2 Chemistry Students. Multi-stage sampling technique, then clustered and random sampling was used. Two research questions and two null hypotheses were tested at 0.05 level of significance which guided the study. Students were taught balancing of chemical equations using Differentiated and Scaffolding Instructional Strategies while the control group were taught using conventional lecture method. The instrument used for data collection was Balancing of Chemical Equation Achievement Test which yielded the reliability of 0.87 using K-R21. The result indicates that the instrument is reliable. The data collected were analysis using descriptive statistic of mean and standard deviation and ANCOVA. The findings, indicates that experimental group 1 and 2 performed better than the control group, with mean gain of 31.70, 31.72, 26.87 respectively. The results also show that there is a significant difference between the the three groups $F(2,262) = 23.123$ and $p\ (0.01) < 0.05$. The significant difference is in favour of the experimental groups which perform better than the control group. Given, the findings of the study, it was recommended among others that Chemistry teachers should incorporate Differentiated and Scaffolding Instructional Strategies in teaching for more achievement and motivation in students.

Keywords: Differentiated and Scaffolding Instructional Strategy, Chemistry Achievement, Gender.

Abbreviations: Kuder-Richardson 21 (K-R21), Differentiation Instructions (DI), Scaffolding Instructions (SI), Conventional Lecture Method (CLM)

1. Introduction

Chemistry is the science that deals with the study of composition, structure, properties, elements, compounds, and reactions with special attention to the atomic and molecular level of matter (Khan, 2024). It's all about the properties of materials and changes they undergo, and everything that happens within these materials. Since the way of life has made people assiduous consumers of products and services that the industry provides to the society. Humanity has also been affected in many stages of its life by diseases that have wiped out a large part of the population, Chemistry played its role as a saving discipline in the manufacture of medicines, antibiotics, and vaccines, as an aid to medicine and biology, to overcome these stages of great mortality (Smith, 2024). Understanding Chemistry principles is essential in preparing today's students to become informed citizens and engaged professionals in tomorrow's society.

Chemistry teachers need to employ innovative teaching methods directly to a conducive classroom environment, and which adjust the content to learners with different backgrounds and talents. Therefore, there is the need for classroom shift from teachers-centred teaching methods to students-centred teaching methods, as effective teaching necessitates students' flexibility, collaboration, creativity, and responsibility to build an educational environment that caters for diverse students population through various approaches such as Differentiated and Scaffolding Instructional Strategies, in order to improve students' achievement in Chemistry. The teaching of Chemistry undoubtedly depends on the effective teaching of the subject, and available resources. One inclusive approach that is often discussed as a possible strategy to react adequately to student's diversity is differentiation, (Tomlinson, 2022).

Differentiation is considered to be an inclusive instructional practice that can be defined as the intentional, systematically planned, and reflected practices that enable teachers to meet the needs of all learners in heterogeneous classrooms (Graham *et al.,* 2021). Differentiated is described as an approach rather than a strategy; it refers to an approach to educators whereby teachers make adjustment to the curriculum and the way they teach to maximize the learning of every student in the class (Bouchrika, 2024). Differentiated Instruction is defined as adjusting lessons to meet students learning needs by using regular assessment data to develop lessons and instructional groups (Tomlinson, 2022). Differentiated Instruction is a philosophy in which teachers tailored teaching to meet student's needs. Unlike other strategies, this is not a singular strategy but a framework that educators can utilize. As such, teachers can execute several DI strategies that work in their particular setting rather than sticking to one. Tomlinson (2022) suggested these four key areas of instructions that educators (teachers) may adjust to better meet the instructional needs of students present. The first is the intended content to be absorbed by the students. The second is how the information is presented to students such as lecture, exploration or project format to ensure better absorption and future usage of the presented information. The third area is the intended outcome of the lesson. The fourth is the learning environment, such as student or community-centred, and types of classroom management techniques. This might include student desks or group tables. Some environments might include a reading nook or allow students to roam freely. (Masinading and Gaylo, 2022). Previous studies have indicated that Differentiated Instruction meet students learning needs.

The methodology behind scaffolding is multi - faceted, Scaffolding refers to the temporary and tailored support provided by teachers to help students successfully perform tasks that they cannot yet complete independently. It involves breaking down complex concepts and providing a supportive framework that is gradually removed as students develop skills and understanding (Academic, 2024). The key features of Scaffolding include ongoing diagnosis of student needs, calibrated and contingent support, promoting learner's autonomy, and fading assistance when mastery is achieved by allowing students to take on more responsibility for their learning (Ray, 2022). Scaffolding helps bridge gaps in skills and understanding. Teachers break tasks into manageable chunks, model processes and strategies, and provide feedback. This allows students to focus on key concepts without getting overwhelmed. Overtime, Scaffolding is diminished as students integrate new knowledge and skills. Scaffolding is often used when introducing new or challenging material, in promoting active learning by encouraging students to build on prior knowledge. It also caters for students' Zone of Proximal Development- what they can achieve with guidance versus what they can do independently. Scaffolding provides temporary support tailored to ability level, which enables educators to differentiate instructions while moving students towards deeper learning. With Scaffolding, the end goal is for students to gain mastery and autonomy (Lesson, 2023).

Student academic achievement refers to what students is able to learn in a determined period of time. The ultimate goal for any teacher is to improve the ability level and prepare students for adulthood (Carter, 2023). Academic achievement is important for successful development of young people in society. Students who do well in school are better able to make the transition into adulthood and to achieve occupational and economic success (Lukman, 2022). Several previous studies have indicated that the teaching method employed in classrooms has a significant impact on students' academic achievement (Isa *et al.,* 2020 and Obafemi, 2022).

The role of gender in schools is evident at multiple levels and exert influence in a variety of ways. There are few gender difference in the academic performance of boys and girls. When differences are apparent, they are small and may be due to motivation more than ability. Despite gender similarities in ability, children and teachers hold stereotypes and material and these stereotypes to the detriment of academic success. Both teachers and students would benefit from increased institutional resources dedicated to addressing issues of sexism and stereotyping. Therefore, delineating femininity and masculinity based on a variety of characteristics, gender represents the distinct features and roles specific to particular00 0groups of individuals concerning their sexuality and sex (Obafemi, 2021).

On the other hand, teachers see female as having less academic potential and which academic failure is attributed more to low ability and less to lack of effort than boys. Conversely, when girls succeed, it is attributed to effort, whereas boys success is attributed to talent or innate ability. Indeed, girls are often praised for their efforts; boys are praised for their ability. Teachers' stereotype views of academic ability also differ by subject, such that teachers overestimate the reading ability of girls and underestimate it in boys, whereas they underrate girls chemistry ability (Kollmayer *et al*., 2018).

1.1 Statement of the Research Problem

Over the years, there has been a lot of mounting stakeholders' criticism of the fallen standard of education in Nigeria. The two major exam bodies publicly known have the same syllabus and each has a regulatory body, aiming at providing an equivalent result. But West African Examination Council (WAEC) and National Examination Council (NECO) has recorded a recurrent poor performance of secondary school students in Chemistry which is considered rather disturbing and embarrassing.

1.2 Research Questions

The following research questions were stated to guide the study:

i What is the mean Achievement scores of students in Chemistry when Differentiated and Scaffolding Instructional Strategy is used?

ii What is the mean Achievement scores of male and female students in Chemistry when Differentiated and Scaffolding Instructional Strategy is used?

Null Research Hypotheses

The null Hypotheses were formulated for the study; which was tested at 0.05 level of significance:

$H0_1$: there is no significant difference on the academic achievement of Students taught Chemistry using Differentiated and Scaffolding Instructional Strategies and those exposed to Conventional Lecture Method

$H0_2$: there is no significant difference between male and female students' Achievement when taught Chemistry using Differentiated and Scaffolding Instructional Strategy and those taught Conventional Lecture Method.

2. Research Methodology

The study adopted quasi experimental research design, precisely pretest, posttest, non-equivalent control group design. A pretest was administered before treatment, while posttest was administered after the treatment. The sample size for the study consisted of 262 senior secondary schools Chemistry students II (SS II) through Multi-stage sampling technique. The instrument used was Balancing of chemical equation test. Reliability of 0.78 was obtained using K-R21. Data collected were analyzed using Descriptive Statistics of mean and Standard Deviation in answering the research questions. Inferential statistics of Analysis of variance (ANOVA) was used to test Null hypotheses, then Analysis of covariance (ANCOVA) was used to show where the significant difference exist.

3. Results

Research Question One: what are the mean achievement scores of students in Chemistry when DI and SI is used?

Table 1: Summary of Analysis of Mean and Standard Deviation on Students' Achievement scores of DI and SI

Group	N	Pretest		Post-test		Mean Gain
		$\bar{X}$	SD	$\bar{X}$	SD	
DI	87	37.53	10.69	69.25	12.37	31.72
SI	97	45.10	8.16	76.80	10.51	31.70
CLM	78	39.54	7.55	66.41	8.17	26.87

Table 1 shows the Mean and Standard deviation analysis of Pre-test and Post-test scores of the two experimental and control group on the achievement in balancing of chemical equation. The table revealed mean and standard deviation scores of the pretest and posttest of experimental group 1 (Differentiated Instruction); Mean = 37.53, SD = 10.14, and Mean = 69.25, SD = 12.37, respectively, with a mean gain of 31.72. Group 2 (Scaffolding Instruction) pretest and posttest Mean = 45.10, SD = 8.16 and Mean = 76.80, SD = 10.51 respectively with mean gain 31.70. While the Conventional lecture method mean and standard deviation for pretest and posttest are X = 39.54, SD = 7.55 and 66.41 and 8.17 with mean gain of 26.87 respectively. The result revealed that experimental group 1, 2 and control group has the mean gain of 31.72, 31.70 and 26.87 respectively, indicating that experimental group 1 and 2 performed better than the control group.

Research Question Two: what is the mean achievement scores of male and female students taught Chemistry using DI and SIS and taught using CLM?

Table 2: Analysis of Mean and Standard Deviation of Gender and Students' Achievement scores of DI and SI and CLM

G	Gender	N	Pretest		Posttest		Mean Gain
			X	SD	X	SD	
DI	M	43	37.44	10.71	90.63	3.98	53.19
	F	44	37.61	10.81	88.11	9.24	50.50
SI	M	48	44.38	8.48	92.17	6.68	47.79
	F	49	45.82	7.86	93.49	6.64	47.67
CLM	M	34	40.12	7.10	74.59	14.89	34.47

F	44	39.09	7.94	79.30	15.82	40.21

Key: M = male, F= female

Table 4.1.3 The table revealed the mean and standard deviation scores of the pretest and posttest of gender in experimental 1(Differentiated Instruction), experimental 2 (Scaffolding Instruction) and control group. DI pretest and posttest male Mean = 37.44, SD = 10.71, and X = 90.63, SD = 3.98, with the mean gain is 53.19, similarly the female Mean = 37.61, SD = 10.81, Mean = 88.11, SD = 9.24, with mean gain 50.50. SI pretest and posttest; male Mean = 44. 38, SD = 8.48, and Mean = 92.17, SD = 6.68 with mean gain 47.79, female Mean = 45.82, SD = 7.86, Mean = 93.49, SD = 6.64 with the mean gain is 47.67 and CLM; male Mean = 40.12, SD = 7.10 and Mean = 74.59, SD = 14.89, with mean gain 34.47, female Mean = 39.09, SD = 7.94 and Mean =79.30, SD = 15.82 with mean gain of 40.21 respectively. The findings indicates that the male and female students taught with DI and SI performed better than those taught with CLM.

Testing of Null Research Hypotheses

Hypotheses One ($H0_1$): There is no significant difference in the mean achievement scores of students taught Chemistry using Differentiated and Scaffolding Instructional Strategies and those exposed to Conventional Lecture Method.

Table 3: Summary of Analysis of ANCOVA of Students' Achievement of Experiment Group 1 and 2 and Control Group.

Source	Type III Sum of Square	Df	Mean Square	F-value	P-value
Corrected Model	17945.716[a]	3	5981.905	95.559	.000
Intercept	17862.876	1	285.354	285.354	.000
Pretest	12780.025	1	204.157	204.157	.000
Group	1579.577	2	12.617	12.617	.000
Error	16150.562	258			
Total	1362375.000	262			
Corrected Total	34096.279	261			

S=Significant at p ≥ 0.05 level

Table 4.1.8 shows F-value (2,262) = 12.617 and p-value of .000 at 0.05 level of significance (p> 0.05). the null hypothesis is rejected. Therefore, there is significant difference in the mean achievement scores of students taught Balancing chemical equations using DI, SI and CLM. Sidak post-hoc multiple comparison was carried out to locate where significant difference exists as presented in Table 4.1.9.

Table 4: Sidak Post-hoc Multiple Comparisons of Experimental 1 & 2 and Control.

(i) Group	(j) Group	Mean Difference(I-j)	p-value	Lower Bound	Upper Bound
DI	SI	-1.591	.489	-4.573	1.390
	CLM	4.424*	.001	1.447	7.401
SI	DI	1.591	.489	-1.390	4.573
	CLM	6.015*	.000	3.031	9.000
CLM	DI	-4.424*	.001	-7.401	-1.447
	SI	-6.015*	.000	-9.000	-3.031

Significant at p ≥ 0.05 level

Table 4 presented the Sidak analysis result of post-test Achievement scores of experimental group 1 and 2 (Differentiated and Scaffolding Instructional Strategies) and control group. The result revealed that there is statistically significant difference between the mean achievement scores of DI and CLM with mean difference of 4.424, $p< 0.05$ with upper bound of 7.401 obtained. There was also significant difference in the mean achievement scores of SI and CLM with mean difference of 6.015 with upper bound of 9.000, in favour of SI and DI. This indicate that students taught balancing of chemical equations using SI then DI performed better then those taught using CLM.

Hypothesis two (HO_2): There is no significant difference between male and female students' Achievement taught Chemistry using Differentiated, Scaffolding Instructional Strategies and Conventional Lecture Method.

Table 5: Shows Summary of ANCOVA Analysis of Students' Achievement of Male and Female of the Experimental Group 1 and 2 and Control Group.

Source	Type III Sum of Squares	Df	Mean Square	F-value	P-value
Corrected Model	18321.723[a]	6	3053.620	49.363	.000
Intercept	17444.697	1	17444.697	281.998	.000
Pretest	12989.770	1	12989.770	209.983	.000
Gender	1955.583	5	391.117	6.323	.000
Error	15774.556	255	61.861		
Total	1362375.000	262			
Corrected Total	34096.279	261			

Significant at 0.05 level

Table 5 presented the Analysis of Covariance (ANCOVA) result of Mean achievement scores of experimental group 1 and 2 (Differentiated and Scaffolding instructional strategy) and control group based on gender. The result indicates that there is a significant difference in the Mean achievement scores of male and female students taught balancing chemical equations using differentiated and scaffolding instructional strategies and those taught using the conventional lecture method, with F-value (5,262) = 6.323, p= (.000) lower than the alpha-level (0.05) p-value (.000> 0.05) is higher than 0.05. Hence, Hypothesis is rejected.

4. Discussion of the Findings

The findings showed that students taught using differentiated and scaffolding performed better than those students taught using conventional lecture method. The result also show there was significant difference in the achievement scores of students taught balancing of chemical equations using DI and SI with those taught CLM which is in favour of the two experimental groups DI and SI group. This finding was in line with Masinading and Gaylo (2022), Nur'aini *et al,* (2023), Onah, (2022), Bulus *et al,(*2021), whose findings shows there was significant difference in mean achievement scores of students taught using DI and SI than those taught using conventional method. The findings showed that learning shifted from the teacher to the students, increases students' achievement of the content. The findings contributed to the understanding DI and SI with respect for students' interests, interactions and views in the cause of learning.

The findings showed that male and female students taught using differentiated instruction performed better than those students taught using scaffolding instructional strategy. The result also show there was significant difference in the achievement scores of male and female students taught Balancing of chemical equations using DI with those taught scaffolding which is in favour of the DI gender. The findings was in line with Mohammed (2019) whose result showed there was statistically significant effect of gender on students' academic achievement, but in contrary to that of Rockmat *et al*, (2019) whose result showed that there was no significant difference on student's gender achievement. The study showed that all the students participated regardless of their gender and diversity as there was interaction between the students.

5. Conclusion

Differentiated and Scaffolding Instructional Strategy were very effective in enhancing the achievement and motivation of students in learning balancing chemical equations, this is probably as a result of contextualizing items, and the use of molecular models, that make the students relates with the concept and also giving them the chance to excel and work with one another as they share ideas. The study also revealed that students showed great enthusiasm for learning and embraces challenges with positive attitude.

DI and SI foster an atmosphere of curiosity and involvement that students' motivation leading to more achievement in cause of the study. This indicates that Differentiated and Scaffolding Instructional Strategy are very effective in the teaching Chemistry students regardless of their diversity.

6. Recommendations

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

1. Chemistry teachers should incorporate the use of Differentiated and Scaffolding Instructional Strategies in teaching Chemistry concepts in secondary schools.

2. Government and stakeholders should make differentiated and scaffolding part of the curriculum at all levels as it is accessible and framework for each subject should be provided for easy guide.
3. Teachers as facilitators should use differentiated and scaffolding strategy to make learning an exciting and enjoyable.

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Article 16

Impact of Technology Integration in Teaching and Learning Process on Academic Performance of Primary School Pupils in Kaduna Metropolis

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Abstract

The study investigated the Impact of Integration of Technology in Teaching and Learning Process on Academic Performance of Primary Schools in Kaduna Metropolis. The study design was quasi-experimental and involved 1586 primary six pupils of both sexes, out of which 197 pupils were sampled using systemic sampling technique. The experiment involved two groups, control group contained pupils in schools taught with traditional method only and experimental group involved pupils in schools taught with multimedia/technology. The instrument for the study was the Basic Science Academic Performance Test (BSAPT). Data were analyzed using one sample and independent t-test. The results revealed that the scores of pupils taught with traditional teaching method were significantly lower (mean score=13.12) ($p \leq 0.05$) than average score of 15 while pupils taught using technology scored significantly higher (mean score = 21.51) ($p \leq 0.05$) than the average score of 15. Based on the findings, it was concluded that technology/multimedia teaching is more effective in improving academic performance of pupils in public schools. The study recommended that educational authorities should encourage teachers to integrate technology in teaching and learning process.

1. Introduction

High quality education system is the backbone of the country. Although slow and steady but there has been a continuous change in the education system. From traditional class room system to smart classrooms. From rote learning methods to problem solving approach. There has been a shift from traditional modes of teaching to smart board learning as every child has a different pace of learning and to give teaching a more customized approach, this change is welcomed by both primary and higher education institutions. Gone are the days when computers and electronic gadgets could only be afforded by the rich. In the Nigeria, modern technology has taken a major part in people's lives, mostly the younger generation. A young student wouldn't consider his/her day complete without having used the internet. This generation of students has often been said to be very adept with computers. Since the innovation of computers, people have been able to acquire information through the internet, online newspapers, online articles, and even online textbooks (Rusell, 2016).

We are living in the era of science and technology where a child starts playing on a touch screen before he learns how to crawl. The power of technology has captured the minds of this generation, this can be seen in the field of education, the technology of teaching students in this competitive scenario is the use of instructional materials like instructional video. In developed countries, teachers use instructional material and new technologies to facilitate learning, while in developing countries like Nigeria, research has it that 80% of teachers still make use of the conventional or traditional method of teaching to facilitate knowledge, this may look boring to the students after a while and the job of a teacher becomes only effective when he is able to pass knowledge to the students and the students are convinced by what is been delivered to them (Salihu and Muhammed, 2015). Numerous researches have indicated the effects of using technology in teaching and learning processes on academic performance of learners; Guan et al., (2018) reported digitally presented lessons significantly improved the scores of pupils assessed by this researcher. Huang et al., (2017) also reported 365 increase in academic performance of participants using integration of technology in lesson delivery. Effiong and Ekpo (2016) investigated the interactive effect of multimedia and power point and utilization on teaching and deduced that it had positive impact on improved cognitive ability of the children involved. Another study conducted by Adeniran et al., (2016) examined the improved retention of key concepts of scientific topics by most of the research participants. Pratama and Setyaningrum (2018) carried out a study on the effect of technology based learning and effective academic performance. Results demonstrated that students who were exposed to technology-based learning, had a positive impact on their problem solving and student learning outcomes. Ibrahim and Hmaid (2017) investigated the effect of teaching using interactive multimedia. They reported that this had a positive effect on school assessment achievement.

1.2 Statement of the Problem

Many of the difficulties pupils face in learning stem from mismatches between the teachers' instructional approaches and pupils' strategies for cognitive intake and processing of the material presented. These mismatches, along with disparate levels of literacy development for pupils within the same grade level, combine to create formidable challenges for the teaching of basic prerequisite areas where student interest is already low. Mounting evidence suggests that pupils generally find most primary school subjects dull and unimportant, that they have difficulty understanding their textbooks, and that overall, they remember very little of what they learned. The problem of this study hinges on a determination of the extent to which the use of technology to achieve instructional effectiveness for enhanced retention and academic performance among primary school pupils in

Kaduna Metropolis, Kaduna State-Nigeria when compared to the use of traditional methods in achieving the same design among pupils.

1.3 Objectives of the Study

The study was guided by the following specific objectives:

i. Determine the academic performance of pupils taught using traditional method in primary schools in Kaduna Metropolis.

ii. Determine the academic performance of pupils taught using technology resources in primary schools in Kaduna Metropolis.

iii. Compare the academic performances of pupils taught using traditional method and pupils taught using technology resources in primary schools in Kaduna Metropolis.

1.4 Research Questions

This study was designed to answer the following research questions:

i. What is the impact of using traditional teaching methods on academic performance of pupils in primary schools in Kaduna Metropolis?

ii. What is the impact of using technology resources on academic performance of pupils in primary schools in Kaduna Metropolis?

iii. What is the difference between academic performance of pupils taught using traditional teaching methods and technology resources in primary schools in Kaduna Metropolis?

1.5 Hypotheses

The following null hypotheses is stated and tested at $p \leq 0.05$ level of significance:

H01. There is no significant impact of using traditional teaching methods on academic performance of pupils in primary schools of Kaduna Metropolis.

H02. There is no significant impact of using technology resources in teaching and learning on academic performance of pupils in primary schools of Kaduna Metropolis.

H03 There is no significant difference in academic performances of pupils taught using traditional teaching methods and pupils taught using technology resources.

2. Research Design

The design of the study was quasi-experimental. It is an impact evaluation that assigns members to the treatment (experimental) group and control group by a method other than random assignment, (National Centre for Technology Innovation (NCTI), 2009). This study used the non-equivalent comparison group designs. According to Salihu (2015), the design requires test for a treated and comparison group. It is a design in which the impact of a treated or intervention are estimated by comparing outcomes of a treatment group and a comparison group.

2.1 Population of the Study

The population of this study consisted of 1586 primary six public school pupils (under KADSUBEB) in Kaduna Metropolis. These pupils were approximately between 10-12 years old. Kaduna metropolis consists of Igabi, Kaduna North, Kaduna South and Chikun Local Government Areas.

2.2 Sample and Sampling Procedures

Intact classes students were used for this study. The choice of the intact class was done in order not to disrupt the normal teaching and learning of academic activities which may not be welcomed by school authorities. The sample size of pupils was selected using systemic sampling technique. The sample size was calculated using 5% margin of error, at confidence level of 80% and 10% population proportion.

Table 2.0 Distribution of pupil participants based on their respective school

Name of School	Total Number of Pupils	Number of sampled pupils
LGEA M/Jos	456	53
LGEA Malali	323	40
LGEA Unguwan Sarki	410	52
Mallam Jalo	397	52
Total	**1586**	**197**

Note: Total Participants=197

2.3 Instrument

Sixteen questions were set at the diagram and parts identification. While the rest of the questions were based on general knowledge of the topics. The questions were examined and corrected by the research supervisors from National Open University of Nigeria (NOUN), Department of Educational Technology.

2.4 Data Collection Procedure

The researcher and one teacher in each school, who were selected based on competence (in technology/multimedia handling and application) were allowed to use Primary 6 lesson periods. Moreover, after adequate preparations, the researcher with the permission of the school management used the relevant available multimedia resources in the school. It was aimed at giving the pupils first-hand information and practical experience on the topic chosen. The experiment involves dividing the sampled pupils into the following groups:

Control Group: This group will be taught the above selected topics with traditional teaching method, then administered the standard academic test and scored accordingly.

Experimental Group: Will involve sampled pupils taught with only technology integrated teaching method, then administered the standard academic test and scored accordingly. The test papers were marked over 30. The test scores for all groups were then collated for comparison sake using the appropriate statistical procedure. The whole data collection procedure lasted for eight (8) weeks.

2.5 Statistical Analysis

The data for the study were the scores from the tests administered to the control and experimental groups. The study used these score percentages and means of scores to analyze the data. The study's research questions were answered using arithmetic mean and standard deviation. One sample t-test was used in testing the null hypotheses 1 and 2., which was analyzed against a pre-determined mean satisfactory test score of 15, while independent t-test was used to test hypothesis 3. All the null hypotheses were tested at $P \leq 0.05$ level of significance.

3. Findings

Research Question 1: What is the impact of using traditional teaching methods on academic performance of pupils in primary schools in Kaduna Metropolis?

Table 3.1 Means, Standard Deviations and Variance of Scores of Basic Science Academic Performance Test (BSAPT) of both Control and Experimental groups.

Test Scores

Group	Mean	N	Std. Deviation	Variance	Range	Maximum	Minimum
Ctrl Grp	13.12*	93	4.648	21.605	21	23	2
Exp Grp	21.51*	104	3.008	9.048	21	28	7
Total	17.55	197	5.704	32.535	26	28	2

Figure 3.1 Mean Scores of Basic Science Academic Performance Test (BSAPT) of Control Group

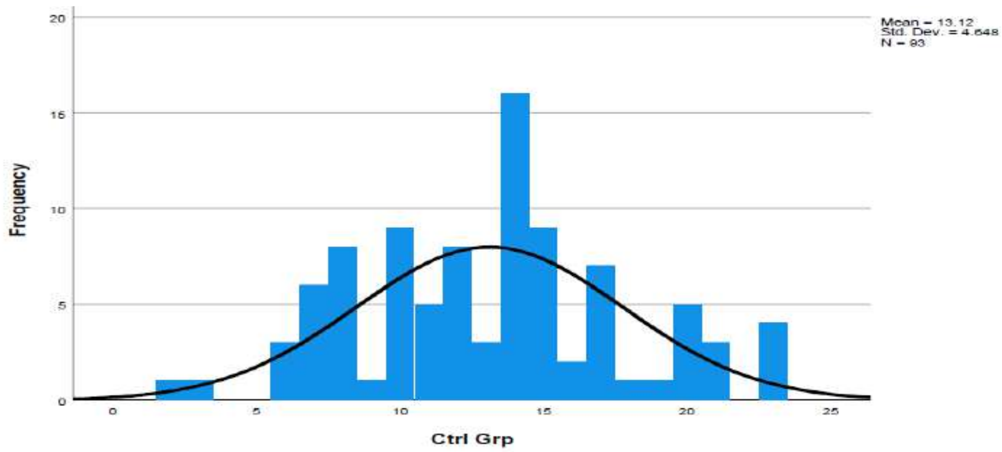

Table 3.1 and figure 3.1 shows that the mean scores of control group (13.12) is much lower than the pre-determined mean pass mark of 15. Therefore, we can deduce that the pupils in control group had insufficient academic performance. This implies that traditional method of teaching has little or lower impact of academic performance of pupils.

Research Question 2: What is the impact of using technology resources on academic performance of pupils in primary schools in Kaduna Metropolis?

Figure 3.2 Mean of Scores of Basic Science Academic Performance Test (BSAPT) of Experimental group

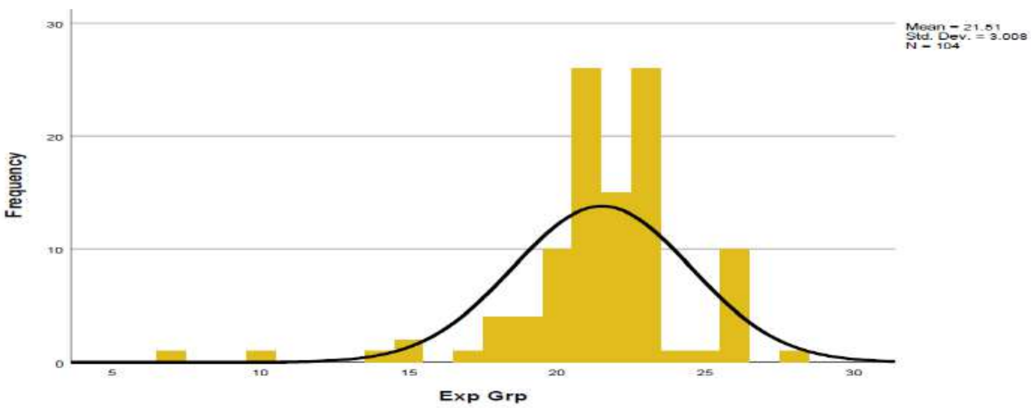

Table 3.2 and figure 3.2 shows that the mean scores of experimental-group (21.51) is much higher than the mean pass mark of 15. Therefore, pupils in this group had satisfactory scores, and performed better academically. This indicates that pupils taught using technology resources are better equipped and performed higher.

Research Question 3: What is the difference between academic performance of pupils taught using traditional teaching methods and technology resources in primary schools in Kaduna Metropolis?

Figure 3.3 Mean Scores of Basic Science Academic Performance Test (BSAPT) of Control and Experimental group

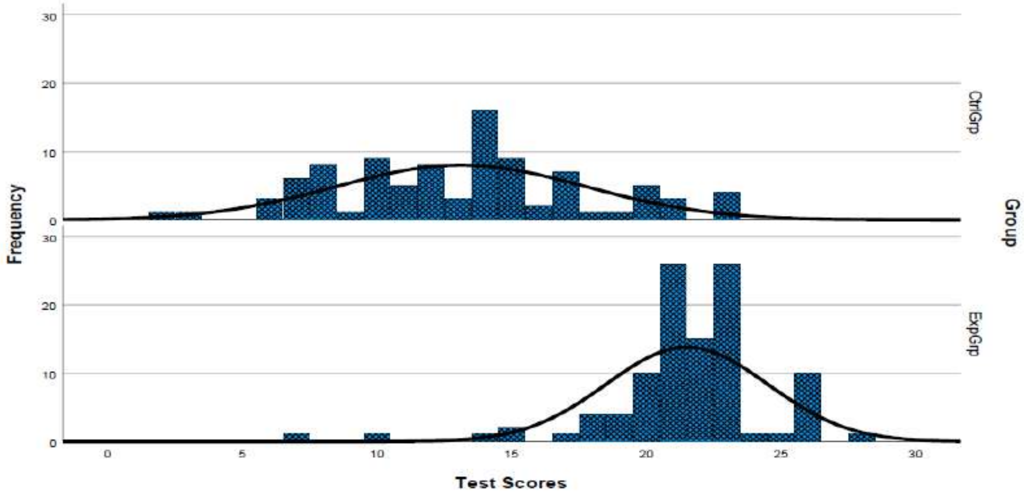

Table 3.2 and figure 3.3 shows the mean scores of control group (13.12) versus experimental group (21.51). This means that pupils in experimental group had higher scores and performed better academically than pupils in control group. This implies that pupils taught with technology resources have better learning opportunity and performed above pupils that were taught using traditional methods.

3.3 Hypotheses Testing

The Formulated null hypotheses one and two were tested with One Sample T-test. Where the mean scores were compared and analyzed with a pre-determined mean score of 15. Hypothesis three was analyzed with Independent Sample T-test. All were tested at $p \leq 0.05$ level of significance.

H01: There is no significant impact of using traditional teaching methods on academic performance of pupils in primary schools of Kaduna Metropolis.

Table 3.2 One-Sample Test Used to Test Hypotheses One and Two

	Test Value = 15					
					95% Confidence Interval of the Difference	
	T	Df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Ctrl Grp	-3.904	92	≤0.05*	-1.882	-2.84	-.92
Exp Grp	22.069	103	≤0.05*	6.510	5.92	7.09

Table 3.3 shows that the mean score of control group (13.12) is significantly lower than the satisfactory score (15) ($p \leq 0.05$). Where Mean difference is -1.882 and T= -3.904. This means that the control group which uses traditional method of teaching performed low in the academic test. Thus, the null hypothesis is rejected.

H02: There is no significant impact of using technology resources in teaching and learning on academic performance of pupils in primary schools of Kaduna Metropolis.

Table 3.2 shows that there is a significant difference between score of experimental group (21.51) and pre-determined mean satisfactory score of 15 ($p \leq 0.05$). Where the mean difference= 6.510 and T=22.069 This means that experimental group which uses technology resources in teaching had significantly higher scores than 15. Therefore, the null hypothesis is rejected.

H03: There is no significant difference in academic performances of pupils taught using traditional teaching methods and pupils taught using technology resources.

Table 3.4 Independent Samples Test for Comparing Scores of Control and Experimental Groups

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	T	Df
Test Scores	Equal variances assumed	22.904	≤0.05*	-15.195	195*
	Equal variances not assumed			-14.850	154.462*

Table 3.4 and 3.3 shows the result of the independent t test of the performance of pupils in control group (13.12) and pupils in the experimental group (21.51) ($p \leq 0.05$). Where F=22.904 and Df=195 This indicates that pupils in the experimental group have higher academic performance compared to pupils in control group. Therefore, the null hypothesis is hereby rejected.

4. Discussion of Findings and Conclusion

The results showed that pupils taught with traditional method had significantly lower scores than the average score of 15. This result no doubt underlines the ineffectiveness of use of traditional teaching methods in primary public schools in Kaduna. Similar research findings reported by authors such as Adeniyi, (2012), Monserate et al., (2018), Noemi et al., (2017), and Harris et al., (2016) all reported similar results, whenever only traditional methods of teaching were used. As reported by the authors traditional method lacks the interactive lesson qualities and ignores the cognitive domain of teaching and learning. Traditional teaching method mostly involves simply writing the lesson contents on the board. Also, it involves the teacher further explaining concepts and processes which are complex on their own especially in science-oriented subjects. Teachers might lack the proper words to use, lacking the ability to properly explain the concepts and processes especially in English Language. It is widely known that English Language proficiency is a challenge for teachers in public schools in especially Northern Nigeria. Few teachers have the quality of perfect articulation and explanation even in local tongues spoken by children in the north. Few teachers can also draw diagrams which are very crucial to the understanding of concepts and how things work in science. Diagrams and charts drawn by teachers might not be at all accurate and might never look like the real thing. All these are limitations which are proven to be detrimental to effective teaching and lesson delivery resulting in poor academic performance.

The second hypothesis was also tested using one sample t-test. The test revealed that the mean scores of Basic Science Academic Performance Test (BSAPT) of pupils in schools taught with technology and multimedia integration was significantly higher ($p \leq 0.05$) than the average score taken as 15. This therefore means that technology integration in teaching improved significantly the academic performance of those pupils. Therefore, the null hypothesis taken here as: no significant impact of technology integration in teaching and learning, is hereby rejected. Pupils performed well above average after learning the selected topics in basic science. Similar results were reported by researchers such as Maganga (2016), Kapur (2018), Bamidele (2013) and Hero (2019). This result is because of using technology/multimedia in teaching by teachers. Teachers were able to properly deliver their lessons efficiently especially using power point presentations. Lesson time was properly conserved and used to optimum. Teachers could display key points using power-point display and explain further each point using concise vocabulary. Teachers displayed quality pictures of especially anatomical structures in these topics involved. These pictures were as close or as similar looking to the real thing as possible. Videos and sounds were also played which were very interesting to the pupils. These lessons were obviously more interesting and engaging. Technology integration her were more student centered and allowed them to develop autonomy and control of their learning of these particular topics. Pupils participated in higher- order thinking, communicated better, solved problems collaboratively, critically reflected on the content of the lessons and expanded general competencies. Using technology here improved memory of pupils of key processes, concepts and anatomical structures. This enabled pupils to score greater marks than average thereby performing better academically. Hypothesis three was tested using independent sample t-test. This null hypothesis states that there is no significant difference in test scores of pupils taught in traditional and technology integrated methods. Results show significant difference ($p \leq 0.05$) between test scores of traditional and technology taught pupils. The scores were significantly higher in pupils taught using technology than the pupils taught with traditional method. Therefore, null hypothesis is hereby rejected. This result was expected because of extensive knowledge and publications on the effectiveness of technology in teaching and the tremendous impact it can have in improving academic performance of primary school pupils.

Osmanovic (2017), Etim and Udo (2016), Popoola et al., (2020) and Midat (2019) all carried similar studies. The results were very similar to the result of this study. Academic performance of pupils taught with technology was always better. This study confirms that technology integration lessons focus learner attention. Basic science teaching strategy was enhanced by the technology/multimedia and traditional method integration also enhanced pupils' positive attitude to the subject. The way technology lessons are presented, helps make relationships between ideas more apparent and helps explain something to the pupil in a manner that hopefully increases retention of the subject matter.

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Article 17

STEMming the Tide: A New Era of Possibilities in Zambia's STEM Education Policy

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Abstract

This study examined the provisions of Zambia's STEM education policy, analysing its direct implications on the country's education system and development. Despite the benefits of STEM education in national development, there have been unclear policy provisions guiding its implementation in Zambia's education sector up until year 2022. To fill this gap, this research studied Zambia's current policies on education to provide insights into how these policies indicate the provision of STEM education in the country. This theoretical study utilized Zambia's policy documents on STEM education provisions. These were analyzed using document analysis, to offer a comprehensive understanding of the policy dictates. The findings indicated that the new education policy, ratified by cabinet provides a rights-based approach for STEM implementation, aligning with the Eighth National Development Plan, which is Zambia's strategic development agenda. This plan emphasizes the provision of STEM education as key for Zambia to achieve its development aspirations of economic transformation and job creation. Furthermore, the 2023 Curriculum Framework has provided for four STEM pathways, offering learners specialized training in Science, Technology, Engineering, and Mathematics. This comprehensive framework is shown to enhance education outcomes, stimulate economic growth, and boost Zambia's competitiveness on a global scale. The implications of this study suggest that while the policy framework is robust, effective implementation, continuous monitoring, and thorough evaluation are essential for realizing its full potential. The study recommends the development of clear guidelines, adequate resource allocation, and professional development for educators to support the successful rollout of the STEM education policy and the 2023 curriculum. By fully harnessing the potential of STEM education, Zambia can drive economic growth, reduce inequality, and promote sustainable development.

Keywords: STEM, policy, education, STEM education, STEM education policy

1. Introduction

In recent years, there has been a growing recognition of the pivotal role that Science, Technology, Engineering, and Mathematics (STEM) education plays in driving national development and economic transformation. Globally, countries have been aligning their education systems to prioritize STEM education as a means of fostering innovation, improving competitiveness, and addressing complex societal challenges. In Zambia, this recognition has culminated in the development and implementation of a robust STEM education policy, which aligns with the broader goals of the Eighth National Development Plan (8NDP**)** and the foundational principles outlined in the Educating Our Future policy.

Historically, STEM education in Zambia has been implemented in a somewhat fragmented manner, often lacking comprehensive policy guidelines that clearly articulated its objectives and implementation strategies. Technical schools, which were initially established with a focus on providing more intensive instruction in the pure natural sciences and technical subjects, gradually began to shift their focus. Over time, these schools started offering the same type of science education as non-technical schools and increasingly incorporated more arts-based subjects into their curricula. This shift diluted the original intent of technical schools, which was to create a distinct and specialized pathway for students interested in STEM fields.

In an attempt to revitalize STEM education, a pilot program was launched in 2019, targeting 15 selected schools. This pilot was implemented in a phased approach, starting with grades 8 and 10, and was designed to reintroduce and strengthen STEM education within these institutions. However, despite the promising start, the implementation of the pilot program was halted due to the lack of clear policy guidelines, even though the existing policy document at the time, *Educating Our Future*, did mention the establishment of schools of excellence, and a cabinet memorandum on the establishment of STEM schools had been ratified in 2019. The absence of explicit policy direction contributed to the stagnation of STEM initiatives within the education system. Recognizing the need for a more structured approach, the Zambian government made significant strides in 2024 by ratifying a new education policy that includes a specific clause on STEM implementation. This marked a turning point in the country's educational reform efforts, providing a clear mandate for the integration of STEM education across the national curriculum. The **8NDP** also provides policy guidelines on the implementation of STEM, emphasizing its importance for achieving Zambia's strategic development goals, particularly in the realms of economic transformation and job creation. Further reinforcing these efforts, the 2023 Curriculum Framework has explicitly taken STEM into consideration, introducing four specialized STEM pathways that offer learners targeted training in Science, Technology, Engineering, and Mathematics. These developments are poised to enhance educational outcomes, stimulate economic growth, and bolster Zambia's competitiveness on the global stage.

This study seeks to explore the provisions of Zambia's STEM education policy, examining its implications for the country's education system and its potential to drive national development. Through a comprehensive analysis of policy documents, this research aims to provide insights into how the STEM education policy, the 2023 Curriculum Framework, and the guidelines provided by the 8NDP can be effectively implemented to achieve Zambia’s developmental aspirations. The study also aims to address the challenges that have previously hindered the full realization of STEM education in Zambia, offering recommendations for moving forward.

1.1. Research Purpose

The purpose of this research was to analyze the provisions of Zambia's STEM education policy. The study aimed to evaluate the adoption and integration of STEM education within the policy framework, providing insights into its potential for promoting STEM education and guiding its implementation in Zambia.

1.2. Research Objectives

The specific objectives of this study are to:

a. Evaluate the clarity of Zambia’s STEM education policy within the country’s strategic goals outlined in the Eighth National Development Plan (8NDP)
b. Assess how the Ministry of Education's strategic framework has adopted and incorporated the STEM education policy.
c. Analyze the integration of STEM education within the 2023 Curriculum Framework and its potential to enhance STEM learning opportunities in Zambia.

1.3. Research Question

Based on the research objectives, the primary research questions for this study were:

a. How clear is Zambia’s STEM education policy within the strategic goals outlined in the Eighth National Development Plan (8NDP)?
b. In what ways has the Ministry of Education's strategic framework adopted and incorporated the STEM education policy?
c. How is STEM education integrated within the 2023 Curriculum Framework, and what is its potential to enhance STEM learning opportunities in Zambia?

1.4. Research Problem

STEM education is increasingly recognized as a critical driver of economic growth, innovation, and social development worldwide. In Zambia, however, the implementation of STEM education has historically been fragmented, lacking clear policy guidelines and a cohesive strategy (World Bank, 2021; UNESCO, 2020). While the establishment of technical schools aimed to provide a strong foundation in science and technology, these schools gradually began offering similar content to non-technical schools and even incorporated more arts-based subjects, diluting their original purpose. This lack of a well-defined policy framework has hindered the consistent and effective implementation of STEM education (Ministry of Education, 1996). Furthermore, the initial attempt to implement STEM education through a pilot program in 2019 was halted due to the absence of clear policy directives, despite existing documents such as Educating Our Future and a cabinet memorandum on establishing STEM schools (Ministry of Education, 2019). The subsequent ratification Ministry of Education's strategic framework, along with the 2023 Curriculum Framework and the Eighth National Development Plan (8NDP), presents an opportunity to address these challenges. However, the provisions within these new policies may not be well understood regarding how they will achieve a comprehensive STEM education. This research analyzed the provisions of Zambia's STEM education policy, evaluating its clarity, adoption, for STEM Education implementation.

1.5. Significance of the Study

This study is significant because it offers a critical examination of the clarity, of Zambia's STEM education policy, providing valuable insights for policymakers, educators, and stakeholders. Moreover, by analyzing how STEM education is integrated into the 2023 Curriculum Framework, the study offers guidance on curriculum implementation strategies that promote STEM fields, thereby helping to build a human resource equipped with the necessary skills for Zambia's future economic needs. Finally, the research aligns with Zambia's strategic development goals outlined in the 8NDP, providing evidence-based recommendations on how STEM education can contribute to economic growth, job creation, and increased global competitiveness.

1.6. Scope and Limitations of the Study

While this study provides valuable insights into the provisions and potential impact of Zambia's STEM education policy, it has several limitations. The research is primarily based on the analysis of policy documents, which may not capture the full complexities of policy implementation at the ground level. There is no empirical data collection from schools, educators, or administrators to provide a more comprehensive understanding of how the policy is being implemented and experienced in practice. Furthermore, the findings of this study are specific to Zambia's context and may not be applicable to other countries with different educational policies, socio-economic conditions, and political environments, limiting the generalizability of the results. The study also adopts a short-term perspective, focusing on the immediate period following the ratification of the STEM education policy in 2024, without considering longer-term trends or the evolving impact of the policy on STEM education in Zambia over time. Additionally, the research is based on the interpretation of policy documents, which may involve subjective judgments. Different stakeholders may interpret the policy provisions differently, potentially affecting the conclusions drawn from the analysis. Addressing these limitations in future research could provide a more comprehensive understanding of the implementation and impact of STEM education policies in Zambia.

2. Literature Review

STEM (Science, Technology, Engineering, and Mathematics) education has gained significant attention globally due to its critical role in driving innovation, economic growth, and workforce development. In recent years, many countries, including Zambia, have focused on integrating STEM education into their national curricula to enhance the quality of education and ensure learners acquire relevant 21st-century skills (Li & Rohayati, 2024; Anh, Hoa, & Phuong, 2024). This literature review examines various studies on STEM education policies, their implementation, and their impact on educational outcomes to contextualize Zambia's efforts within the broader landscape of global STEM education reform.

A study by Li and Rohayati (2024) emphasizes the importance of aligning learning outcomes with competence development, particularly in cross-border e-commerce education. This study reveals that clear policy frameworks and targeted assessment strategies are essential to ensure that educational institutions produce graduates with the necessary competencies to meet market demands.

Anh, Hoa, and Phuong (2024) also highlight the effectiveness of a competency-based approach in assessing students' learning outcomes. Their study found that a well-structured curriculum and the use of formative assessments are crucial in promoting critical thinking, problem-solving, and practical application skills among students.

2.1. Research Gap

While the literature highlights the critical role of clear policy frameworks, competency-based curricula, and teacher capacity building in the successful implementation of STEM education, there remains inadequate analysis on how these components are integrated and operationalized within Zambia’s educational context. This study addresses this gap by evaluating the clarity, adoption, and integration of Zambia’s STEM education policy within the broader context of the Eighth National Development Plan (8NDP), the Ministry of Education's Strategic Plan (2022-2026), and the 2023 Curriculum Framework. It aims to provide understanding of how these policies are planned to be implemented and their potential impact on Zambia's education system and socio-economic development.

3. Methodology

3.1. Research Design

This study employed a qualitative research design, utilizing a document analysis approach to examine the provisions of Zambia's newly ratified STEM education policy. The design was chosen to provide an in-depth understanding of the policy framework, within the broader context of Zambia's educational goals as outlined in the Eighth National Development Plan (8NDP) and the 2023 Curriculum Framework. Document analysis was appropriate for this research because it allowed for a comprehensive evaluation of the policy literature, to identify key themes from the provisions.

3.2. Target, Sampling Procedure and Data Collection

The target of this study were 3 official policy documents related to STEM education in Zambia. These documents were purposively selected because they provide direct insights into the intentions, guidelines, and expected outcomes of Zambia's STEM education initiatives. The data for this study was collected from the official policy documents and government reports to provide a comprehensive understanding of Zambia's STEM education policy framework. The primary sources included, the Eighth National Development Plan (8NDP) which outlines Zambia's national development goals, emphasizing the role of STEM education in fostering economic transformation and job creation. The Ministry of Education's Strategic Framework was also reviewed to understand the Ministry's priorities and strategies, particularly concerning the adoption and integration of STEM education. Furthermore, the 2023 Curriculum Framework provided insights into how STEM pathways are integrated into the national curriculum.

3.3. Data Analysis

Data analysis involved a thematic analysis approach, where the collected documents were systematically reviewed to identify recurring themes, key provisions, and gaps related to the adoption, integration, and implementation of STEM education. Each document was analyzed to assess how it addresses the research objectives, focusing on three main areas: clarity of policy provisions, the adoption of the policy within the Ministry of Education’s framework, and the integration of STEM education within the 2023 Curriculum Framework. Findings were categorized based on these themes to provide a comprehensive understanding of how STEM education is conceptualized and operationalized in Zambia’s policy landscape.

3.4. Validity and Reliability

To ensure validity, the study focused on using official documents that are directly relevant to the research objectives. Triangulation was employed by analyzing multiple policy documents from to cross-check and corroborate the findings. This approach minimizes the risk of bias and enhances the credibility of the results by providing multiple perspectives on the same issues. Reliability was addressed by the researcher maintenance of an audit trail of the analysis process, including notes and reflections on how decisions were made, to ensure transparency and replicability.

3.5. Ethical Considerations

The study adhered to ethical guidelines for research involving public documents and data. Since the research was based on publicly available documents, issues of confidentiality and privacy were minimized. However, the researcher ensured that all documents were accurately represented and interpreted to avoid any misrepresentation of the content. Proper citation and acknowledgment of all sources were maintained throughout the study to ensure academic integrity and avoid plagiarism. Additionally, the researcher was mindful of any potential biases in interpreting the policy documents and took steps to present the findings objectively and fairly.

4. Findings

The results in this paper are systematically presented to provide a comprehensive understanding of how Zambia's STEM education policy is being integrated and implemented across various educational frameworks and strategies. The findings are organized according to key research objectives, beginning with an analysis of STEM policy within the Eighth National Development Plan (8NDP), followed by an assessment of how the Ministry of Education's strategic framework has adopted and incorporated STEM education. The results are structured using narrative explanations in detailed tables.

4.1. Zambia’s STEM Education Policy within the Strategic Goals Outlined in the Eighth National Development Plan (8NDP)

Table 1 provides findings, demonstrating how the 8NDP frames STEM education as a strategic priority for achieving Zambia’s development goals. The table highlights the key themes identified within the 8NDP that relate to the strategic emphasis on STEM education, its inclusion in curriculum and skills development, and the support for science, technology, and innovation.

Table 3:Zambia’s STEM Education Policy within the Strategic Goals Outlined in the Eighth National Development Plan (8NDP)

Theme	Description

Strategic Emphasis on STEM Education	The 8NDP identifies STEM education as a key component of Zambia's "Improved Education and Skills Development" strategy, aligning it with national objectives such as economic transformation and job creation (8NDP, 2022-2026, p. 49-50).
Inclusion of STEM in Curriculum and Skills Development	The 8NDP outlines strategies for incorporating STEM into the national curriculum, including curriculum reviews to increase learners' uptake of science and technology and the integration of TEVET skills at the secondary level (8NDP, 2022-2026, p. 50).
Support for Science, Technology, and Innovation	The 8NDP commits to enhancing science, technology, and innovation through increased investment in research and development, as well as partnerships between higher education institutions, industry, and stakeholders (8NDP, 2022-2026, p. 52).

The findings from the analysis of the Eighth National Development Plan (8NDP) regarding the Zambia's STEM education policy indicate the government's recognition of the vital role of STEM education in driving national progress such as economic transformation, job creation, and fostering an innovative society.

4.2. Alignment of STEM Education within the Ministry of Education's Strategic Plan

To address Objective 2, which is to assess how the Ministry of Education's strategic framework has adopted and incorporated the STEM education policy, Table 2 below presents the findings. It reveals a strong emphasis on STEM education as a critical component of Zambia's educational development over a period of five years (2022-2026).

Table 4:Alignment of STEM Education within the Ministry of Education's Strategic Plan

Strategic Objective	Initiatives/Strategies	Intended Results	Targets (2022-2026)
Improve Learning Achievements	Reform education curriculum to ensure holistic accelerated education and skills development in STEM.	Enhance quality and relevance of education to ensure learners acquire 21st-century competencies.	Curriculum reforms implemented to include STEM education (Ministry of Education, 2022, p. 28).
Prioritize Investment in STEM	Develop and procure STEM teaching and learning materials for schools.	All STEM schools provided with necessary teaching materials to support effective STEM education.	Increase coverage from 70% in 2022 to 90% by 2026 (Ministry of Education, 2022, p. 28).

Enhance Learning Infrastructure	Renovate, rehabilitate, maintain, and construct specialized rooms, equipment, and machinery to support STEM teaching and learning.	Schools equipped with specialized facilities for effective STEM education delivery.	75% of schools to have specialized rooms renovated or constructed by 2026 (Ministry of Education, 2022, p. 28).
Train Teachers in STEM Pedagogy	Train lecturers and teachers in various aspects of pedagogy to enhance their skills and competencies in STEM.	Teachers are well-prepared to deliver high-quality STEM education.	Increase from 55% in 2022 to 75% of eligible teachers trained by 2026 (Ministry of Education, 2022, p. 28).

The results indicate that the Ministry's Strategic Plan (2022-2026) demonstrates a clear commitment to integrating STEM education as a priority for improving educational outcomes. The focus on curriculum reform, infrastructure development, teacher training, and the provision of necessary learning materials underscores the Ministry's strategy to build a strong foundation for STEM education that aligns with Zambia's national development goals.

4.3. Integration of STEM Education within the 2023 Curriculum Framework

Table 3 presents the findings on how STEM education is integrated across different educational levels in Zambia according to the 2023 Curriculum Framework. It starts with foundational STEM concepts in primary education and advancing to more specialized STEM pathways at the Ordinary and Advanced levels.

Table 5:Integration of STEM Education within the 2023 Curriculum Framework

Level	Pathways Offered	STEM Integration and Subject Requirements
Primary Level	General curriculum (not explicitly labeled as STEM)	**STEM Foundations:**
		Science is introduced as a general subject focusing on basic concepts such as living and non-living things, the environment, plants, animals, and simple experiments that foster inquiry-based learning.
		Mathematics is a core subject, covering basic arithmetic, shapes, measurements, and patterns, foundational to advanced mathematical concepts.

		Technology and Engineering Concepts are integrated through practical activities and learning tools that encourage problem-solving, creativity, and critical thinking, although not explicitly labeled as "engineering" or "technology." These foundational elements help develop curiosity, analytical thinking, and a basic understanding of scientific and mathematical principles, setting the groundwork for specialized STEM learning in secondary school.
Ordinary Level	Eight pathways: Social Sciences, Natural Sciences, Business and Finance, Agriculture, Home Economics and Hospitality, Technology, Performing and Creative Arts, STEM.	**Four STEM Pathways:**
		Natural Sciences: Compulsory subjects include English Language, Mathematics, Biology, Chemistry, and Physics.
		Technology: Focuses on subjects like Mathematics, Science, Information and Communication Technology (ICT), and Design and Technology.
		Home Economics and Hospitality (STEM): Compulsory subjects include English Language and Mathematics, with additional subjects like Food and Nutrition, and Hospitality Studies.
		Agriculture (STEM): Compulsory subjects include English Language, Mathematics, and Agricultural Science, promoting skills in crop and animal production, as well as farm management (2023 Curriculum Framework, p. 4.3.1.2).
Advanced Level	Five pathways: STEM, Social Sciences and Languages, Business Studies, Sports Science, Creative Arts.	**STEM Pathway:** Subjects at the Advanced level are clustered under the STEM pathway to provide focused training in Science, Technology, Engineering, and Mathematics. This pathway is designed to deepen learners' expertise and prepare them for higher education and careers in STEM-related fields (2023 Curriculum Framework, p. 4.3.1.2).

This result shows the integration of STEM education within the 2023 Curriculum Framework at various educational levels. At the primary level, foundational elements of STEM are introduced through general subjects, fostering essential skills in science, mathematics, and technology. At the ordinary level, four distinct STEM pathways are provided to ensure a strong emphasis on scientific, technical, and vocational education. At the advanced level, a dedicated STEM pathway offers specialized training, preparing students for further education and professional careers in STEM-related fields.

5. Discussion

The discussion in this paper focuses on evaluating Zambia's STEM education policy through the three key objectives. The discussion begins by examining STEM policy within the 8NDP, highlighting how the policy is positioned to support Zambia's broader goals of economic transformation and job creation. It then analyzes how the Ministry of Education's strategic plan adopts and operationalizes the STEM education policy, focusing on initiatives such as curriculum reforms, infrastructure development, and teacher training. Finally, the discussion assesses the integration of STEM pathways within the 2023 Curriculum Framework.

5.1. Zambia's STEM Education Policy within the Strategic Goals Outlined in the Eighth National Development Plan (8NDP)

The analysis of the Eighth National Development Plan (8NDP) provides valuable insights into the clarity and alignment of Zambia's STEM education policy within the country's broader strategic goals. The findings reveal that the 8NDP identifies STEM education as a crucial element of its "Improved Education and Skills Development" strategy, directly linking it to national objectives such as economic transformation and job creation (8NDP, 2022-2026, p. 49-50). The plan clearly positions STEM education as central to achieving these goals, reflecting a strong policy emphasis on its importance.

Furthermore, the 8NDP outlines specific strategies for integrating STEM into the national curriculum. It emphasizes the need for curriculum reviews to enhance learners' uptake of science and technology and promotes the integration of Technical and Vocational Education and Training (TEVET) skills at the secondary level (8NDP, 2022-2026, p. 50). This approach aims to build a solid foundation for STEM education, ensuring that it is embedded within the national education system from an early age.

Additionally, the 8NDP commits to supporting science, technology, and innovation through increased investment in research and development. It also highlights the importance of fostering partnerships between higher education institutions, industry, and other stakeholders to enhance STEM-related activities (8NDP, 2022-2026, p. 52). This commitment reflects the government's recognition of the critical role of STEM education in driving innovation and competitiveness at both the national and international levels.

5.2. Alignment of STEM Education within the Ministry of Education's Strategic Plan

The incorporation of STEM education within the Ministry of Education's strategic plan has several implications. Firstly, the emphasis on curriculum reform and investment in STEM resources indicates a move towards a more competency-based education system, which is crucial for preparing students for future challenges and opportunities in a rapidly changing global environment (Baird et al., 2017; Biggs & Tang, 2011). Secondly, the focus on infrastructure development and specialized learning environments reflects an understanding of the importance of providing adequate facilities for effective STEM teaching and learning (Li & Rohayati, 2024).

Moreover, the prioritization of teacher training in STEM pedagogy is critical for ensuring that educators are equipped with the necessary skills to deliver high-quality STEM education. This aligns with international best practices, which emphasize the need for continuous professional development to improve teaching effectiveness (Anh, Hoa, & Phuong, 2024; Wiliam, 2018). However, the success of these initiatives will depend on effective implementation, including adequate funding, timely provision of resources, and ongoing support for teachers and schools.

Committing to these strategic objectives, the Ministry of Education is positioning Zambia to achieve its educational development goals, enhance STEM competency among learners, and contribute to the country’s broader socio-economic transformation. However, challenges such as ensuring equitable access to resources and addressing disparities between urban and rural schools must be managed to achieve the desired outcomes fully (Republic of Zambia, 2022).

5.3. Integration of STEM Education within the 2023 Curriculum Framework

The analysis of the 2023 Curriculum Framework reveals a comprehensive approach to integrating STEM education across all levels of Zambia's educational system. At the primary level, foundational STEM elements are introduced through general subjects like Science and Mathematics, along with the integration of Technology and Engineering concepts through practical activities. This early introduction of STEM subjects is essential for fostering inquiry-based learning, critical thinking, problem-solving, and creativity in young learners, which are crucial competencies for their future academic and professional pursuits (Hofstein & Lunetta, 2004; Millar, 2004). Although STEM is not explicitly labeled as a separate pathway at this level, the inclusion of these foundational concepts ensures that students develop early competencies that are necessary for more specialized STEM learning in later years. Such an approach aligns with global best practices that emphasize the importance of building a strong foundation in STEM subjects from an early age to stimulate interest and proficiency in these fields (Li & Rohayati, 2024; Sonnleitner & Ruffeis, 2023).

At the ordinary level, the curriculum becomes more structured, offering eight distinct pathways, four of which are explicitly STEM-related: Natural Sciences, Technology, Home Economics and Hospitality, and Agriculture. This level allows students to engage more deeply with STEM subjects, such as Biology, Chemistry, Physics, Mathematics, and Information and Communication Technology (ICT). The inclusion of subjects like Agricultural Science and Design and Technology diversifies STEM education by linking theoretical knowledge with practical, real-world applications (Vänttinen, 2023). This diversified approach ensures that learners are not only academically prepared but also equipped with vocational skills that can be applied directly in various sectors of the economy, which is crucial for fostering a workforce that is responsive to both local and global labor market demands (Biggs & Tang, 2011).

At the advanced level, the curriculum offers a dedicated STEM pathway that clusters subjects to provide focused training in Science, Technology, Engineering, and Mathematics. This specialized pathway is designed to deepen learners' expertise and prepare them for higher education and careers in STEM-related fields. The structured and focused nature of this pathway reflects a commitment to cultivating a workforce with strong STEM competencies, which are increasingly in demand in both the local and global job markets (Baird et al., 2017). The emphasis on specialized STEM education at the advanced level is consistent with international trends that prioritize STEM disciplines to drive innovation and economic growth (Wiliam, 2018).

The integration of STEM education within the 2023 Curriculum Framework has several important implications for Zambia's educational and socio-economic landscape. By introducing foundational STEM concepts at the primary level and progressively building on them through specialized pathways at the ordinary and advanced levels, the curriculum framework is well-positioned to enhance the overall STEM competencies of learners. This could lead to improved learning outcomes in STEM subjects and a stronger pipeline of students prepared for higher education and careers in science, technology, engineering, and mathematics (Li & Rohayati, 2024). Additionally, the curriculum's emphasis on STEM education aligns closely with Zambia's strategic development objectives, as outlined in the Eighth National Development Plan (8NDP). By preparing a skilled workforce equipped with critical STEM skills, the curriculum supports broader goals of economic transformation, job creation, and innovation, ensuring that the education system contributes meaningfully to national development efforts (Republic of Zambia, 2022).

Furthermore, the curriculum's approach to integrating STEM at multiple levels, with pathways that include diverse subjects such as Agriculture and Home Economics, reflects a commitment to inclusivity. This inclusive approach allows students from various backgrounds and interests to engage with STEM in ways that are relevant to their contexts and aspirations, which is critical for ensuring equitable access to quality education and promoting diversity in STEM fields (Anh et al., 2024). Additionally, the focus on technology and practical applications within the curriculum prepares students for a rapidly evolving, technology-driven economy. Skills in areas such as ICT, design, and digital literacy are critical for future employment opportunities, and their inclusion in the curriculum reflects a forward-looking approach to education that prioritizes relevance and adaptability (Sonnleitner & Ruffeis, 2023).

However, while the framework provides a strong foundation for STEM education, its success will depend heavily on effective implementation. This includes adequate resource allocation, teacher training, infrastructure development, and continuous monitoring and evaluation to ensure that the curriculum's goals are met. Without these supports, there is a risk that the integration of STEM pathways may not achieve its full potential, leading to gaps in student preparedness and workforce readiness (Biggs & Tang, 2011; Wiliam, 2018). Therefore, the realization of the benefits of the

2023 Curriculum Framework will require a sustained commitment to addressing the practical challenges of implementation, ensuring that all learners have the opportunity to succeed in STEM fields.

6. Conclusion

This research critically examined Zambia's STEM education policy, focusing on its alignment with the strategic goals outlined in the Eighth National Development Plan (8NDP), its incorporation into the Ministry of Education's Strategic Plan (2022-2026), and its integration within the 2023 Curriculum Framework. The findings reveal that the STEM education policy is strategically emphasized in the 8NDP, aligning with national goals for economic transformation, job creation, and innovation.

The analysis of the Ministry of Education's Strategic Plan further shows a strong commitment to advancing STEM education through various initiatives, including curriculum reform, investment in STEM teaching materials, infrastructure development, and teacher training. These strategies are designed to enhance the quality and relevance of STEM education, ensuring that learners acquire 21st-century competencies. Nevertheless, the success of these initiatives is contingent upon effective implementation, adequate funding, and continuous monitoring and evaluation.

The review of the 2023 Curriculum Framework indicates a well-structured approach to integrating STEM education across all levels, from primary to advanced. This framework also establishes specific pathways and subject combinations to promote STEM learning. To ensure effective implementation of Zambia's STEM education policy, it is recommended that the Ministry of Education prioritize teacher capacity building through comprehensive professional development programs. These programs should focus on enhancing teachers' skills in STEM pedagogy, including inquiry-based learning, digital literacy, and the integration of technology in teaching and learning.

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