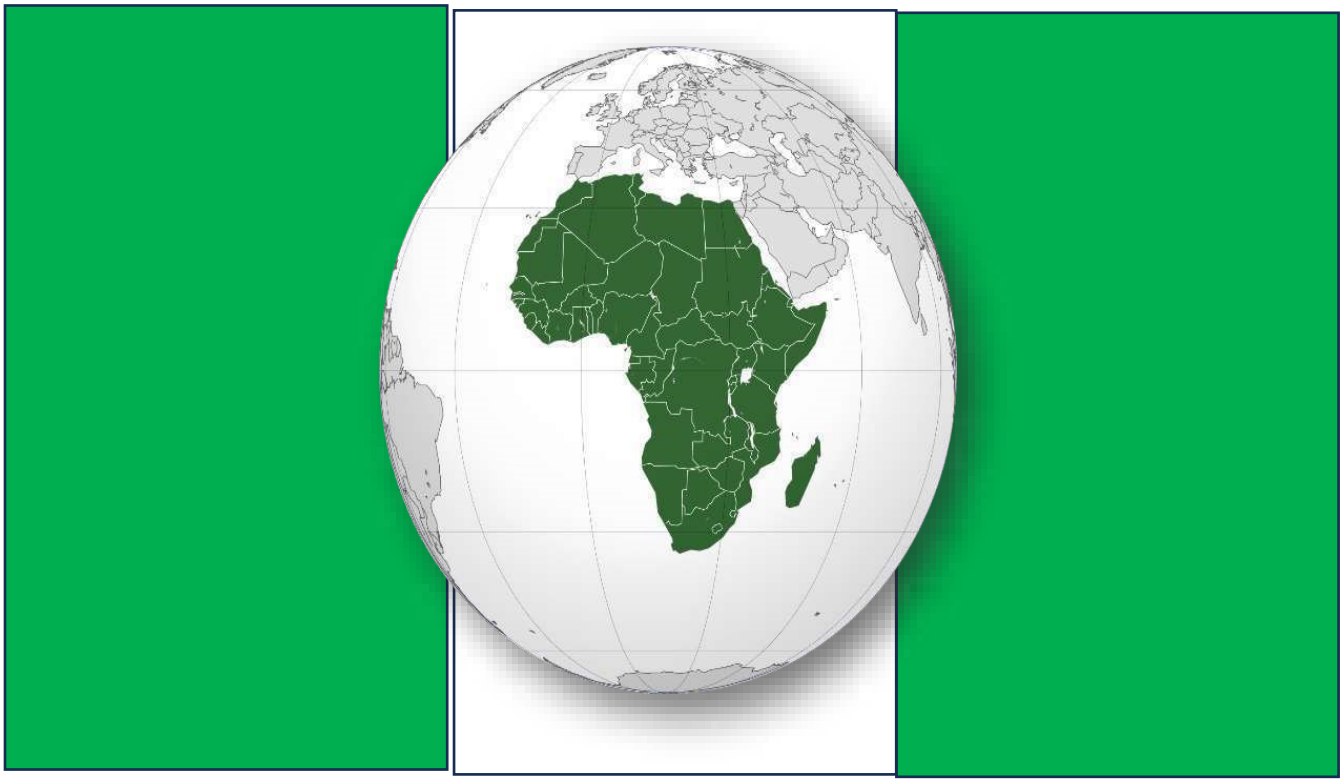
ISSN 2617-6300

Strengthening Mathematics and Science Education in Africa

[SMASE-AFRICA]

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



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

Volume I, Number 3, July, 2025

[Published] July 2025, Nairobi, Kenya

[Copyrights] ISSN 2617-6300

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Strengthening Mathematics and Science Education in Africa

SMASE-AFRICA

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Preface

Welcome to Volume 1, Number 3, July, 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 **sixteen (16) 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 third 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 and Yahaya Sani Rigachikun, in the study titled ***Enhancing Learners' Academic Achievement through Hands-on Learning: An Exploratory Study on Factors, Prime Factors, and HCF of Numbers among Basic Education Learners at National Teachers Institute (NTI) Demonstration School, Rigachikun, Kaduna Nigeria,*** investigated the role of innovative hands-on learning in improving the teaching and learning of mathematics. The study focused on Basic Education 1 learners' understanding of factors, prime factors, and the highest common factors (HCF) of numbers. A quasi-experimental design was employed with 60 learners randomly assigned to experimental and control groups. Two research questions were raised and answered using mean and standard deviation, while two null hypotheses were tested at the 0.05 level of significance. A Mathematics Achievement Test (MAT), developed by the researcher and validated by two experts in measurement and evaluation, served as the instrument for data collection. The experimental group received hands-on instruction, while the control group was taught with traditional methods, and both groups were administered pre- and post-tests. Results showed significant differences in achievement, with the experimental group performing better than the control group. The study suggested that integrating hands-on activities and simulations enhanced learners' conceptual understanding, engagement, and deeper learning. The findings highlighted the potential of hands-on learning to improve academic achievement among Basic Education learners in Nigeria.

Article 2

Oginni O.I**,** in the study titled ***Animated-Cartoons Aided Instructional Package and Pupils' Achievement in Mathematics,*** investigated the effectiveness of animated-cartoons aided instructional package on pupils' achievement in Mathematics in Ekiti State primary schools. The study adopted a pre-test, post-test, control group quasi-experimental design. The population comprised 18,215 Primary II pupils across 911 public primary schools in Ekiti State as recorded by the Ekiti State Universal Basic Education Board in 2023. A sample of 74 Primary II pupils was selected using a multi-stage sampling procedure. The instrument for the study was the Mathematics Achievement Test (MAT), which was scrutinized by experts in Mathematics Education for face and content validity. Reliability was established using the test-retest method, administered twice within two weeks on 20 pupils outside the sample, and analyzed using Pearson's Product Moment Correlation, yielding a reliability coefficient of 0.85. The experimental procedure was carried out in four stages, and the data collected were analyzed using descriptive and inferential statistics. The findings showed that the use of animated-cartoons aided

instructional package was effective in improving pupils' achievement in Mathematics. There was a significant difference in the post-test mean scores of pupils in the experimental and control groups, and the retention level of pupils taught Mathematics using animated-cartoons was found to be high. The study also revealed no significant difference in the mean scores of pupils exposed to the animated-cartoons aided instructional package based on school location. Based on these findings, it was recommended that teachers should be trained to use animated-cartoons aided instructional packages to improve pupils' retention and achievement in Mathematics in primary schools.

Article 3

Integrating Aquaculture into STEM Curriculum: Evaluating Water Quality, Growth Performance, Nutrient Utilization, and Survival of Clarias gariepinus (Burchell, 1822) Juveniles at Different Stocking Densities in Plastic Bowls by Ishaq M.S., Musa A.S., Ahmed H., Tukur M., and Shuaibu Z.M analyzed the effects of stocking density on water quality, growth performance, nutrient utilization, and survival of African Catfish (Clarias gariepinus) juveniles reared in plastic bowls, with emphasis on integrating aquaculture into the STEM curriculum. Overstocking was observed to increase stress, leading to higher energy requirements and reduced growth rates and food utilization. Groups of 225 fish were stocked at densities of 5, 10, 15, 20, and 25 fish per bowl in triplicate, with initial mean weights ranging from 9.27 to 10.30 grams. Over a 56-day trial conducted from April to June, the fish were fed 5% of their body weight twice daily. Final mean weights for the different densities were 79.08, 86.65, 75.60, 74.08, and 85.24 grams, respectively. Water quality parameters monitored included temperatures ranging from 22.9°C to 30.9°C, pH values from 6.6 to 7.0, and dissolved oxygen levels from 2.5 mg/L to 6.5 mg/L. Statistical analysis revealed significant impacts of stocking density on all measured parameters, underscoring the importance of aquaculture in STEM education. Lower stocking densities produced better growth and survival rates, highlighting the value of incorporating aquaculture projects into the STEM curriculum to enhance learning and the practical application of scientific principles. The study recommended that schools develop a structured curriculum incorporating aquaculture projects with clear learning objectives and assessment criteria.

Article 4

Anecetus Moonga, Emmanuel Mwape, and Benson Banda, in the article titled ***Coding for Beginners: A Case of Boot Camp of 40 Learners in Lusaka District, Zambia,*** **investigated** the effectiveness of a coding boot camp program designed for beginners in Zambia's capital district. Recognizing the growing global demand for coding skills and the barriers many individuals in developing countries face in accessing digital training, the study sought to evaluate how short, intensive training could contribute to bridging the digital divide. A mixed-methods approach was employed, combining quantitative and qualitative data collection methods. Forty learners participated in a 12-week coding boot camp, with their learning outcomes measured through pre- and post-tests alongside semi-structured interviews to capture perceptions of the program. Results indicated that the boot camp was effective in equipping participants with basic programming skills, showing significant improvements in their coding abilities after completing the program.The study emphasized the importance of affordable and accessible coding programs in enabling broader

participation in the digital economy. It suggested that coding boot camps could serve as a practical pathway for skill acquisition, while recommending further research into their long-term impact on individuals and communities. Policymakers and organizations were urged to invest in such initiatives to expand opportunities, improve digital literacy, and prepare societies for the demands of the modern digital age.

Article 5

The Influence of SMASE Practical Approach Toward's Enhancing the Teaching of STEM Subjects in Kudan Local Government Area of Kaduna State Nigeria by Yashim Jagaba Mathias examined the impact of the Strengthening Mathematics and Science Education (SMASE) practical approach, specifically the Activity, Student-Centered, Experiment, and Improvisation – Plan, Do, See, and Improve (ASEI-PDSI) model, on enhancing STEM education in Kudan Local Government Area, Kaduna State. The research aimed to foster positive changes in teachers' attitudes toward their profession, particularly in the teaching of mathematics and science, by improving subject mastery, pedagogical skills, resource utilization, and student engagement in classroom activities. It also sought to strengthen teachers' ability to deliver student-centered lessons through well-planned ASEI lessons. The SMASE initiative, designed to elevate the quality of STEM education, trained 34 teachers from various disciplines including mathematics, engineering, science, robotics, and agriculture, using the ASEI-PDSI approach. Two versions of a 25-item questionnaire, covering categories A to E, were administered to the teachers before and after the training sessions. The pre-INSET questionnaire was administered before the sessions commenced, and the post-INSET questionnaire at the conclusion. Participants responded to each item on a 5-point scale, with scores interpreted as follows: a mean score (m) below 3.0 indicated a negative attitude, $4.0 \leq m < 4.5$ suggested a shift toward a positive attitude, $m \geq 4.5$ reflected a positive attitude, and $3.0 \leq m \leq 3.9$ denoted neutrality. The results demonstrated that teachers reported increased confidence and effectiveness in delivering STEM content. The study concluded that the SMASE practical approach (ASEI-PDSI) was a viable and effective strategy for enhancing STEM education and recommended broader adoption and ongoing professional development to sustain and expand these positive outcomes.

Article 6

Byukusenge Celine, Nkundabakura Pheneas, Nsengimana Theophile, and Uwamariya Eugenie**, in** the study titled ***Impact of Continuous Professional Development on Rwandan Mathematics and Science Teachers' Proficiency in Utilizing Modernized Instructional Tools and Innovative Pedagogy,*** assessed the impact of the Rwanda Quality Basic Education for Human Capital Development (RQBEHCD) project on Mathematics and Science education in Rwanda. The project emphasized continuous professional development in Innovative Teaching Mathematics and Science (CPD-ITMS) for teachers from upper primary to lower secondary levels. The CPD focused on enhancing teachers' proficiency in utilizing modern instructional tools and applying

innovative pedagogies, particularly the 5Es instructional model (Engage, Explore, Explain, Elaborate, Evaluate). The research employed a mixed-methods approach, incorporating classroom observations and semi-structured interviews with a sample of 62 teachers. The study highlighted the effective use of modern instructional tools, with 81% of the observed teachers using projectors and computers provided by the program. It was also found that 59% of teachers used scripted lessons in teaching, while 41% did not. Among those who used scripted lessons, 90% were able to use them effectively and completely. Furthermore, the findings showed a high adoption rate of the 5Es model (84%), although the elaborate phase was the least implemented. Interview results revealed persistent challenges for teachers, such as poor or absent internet connectivity, lack of electricity in classrooms, and unsupportive school leaders. The study recommended thorough follow-up and sensitization at the school level to ensure that CPD programs achieve their intended outcomes and strengthen Mathematics and Science education in Rwanda.

Article 7

The Implementation and Impact of the Montessori STEM Curriculum for Girls in Northern Nigeria: A Case Study of Zaria and Sabon Gari Local Government Area, Kaduna State by Bello Khadijah Aminu, Salisu Lubabatu Ahmad, and Habiba Mohammed examined the transformative role of the Montessori STEM curriculum in addressing the unique educational challenges and opportunities faced by girls in northern Nigeria. The curriculum emphasized hands-on, experiential learning and student-centered discovery, fostering an environment where girls could develop critical thinking, creativity, and problem-solving skills. By integrating interdisciplinary learning, the Montessori STEM approach enabled students to recognize the connections between scientific concepts and real-world applications, thereby making learning more relevant and engaging. In a context where gender disparities and limited access to education posed significant obstacles, the Montessori STEM curriculum provided an inclusive and empowering framework. It created a prepared environment where girls were encouraged to explore, experiment, and engage with STEM subjects freely, helping to challenge stereotypes and break barriers that often prevented them from pursuing STEM careers. The Montessori method's emphasis on practical life skills, sensorial experiences, and project-based learning further equipped girls with the tools and confidence to succeed in STEM fields. Teachers acted as facilitators, guiding students through individual learning journeys and fostering supportive communities that valued each learner's contributions. Research findings indicated that Montessori education significantly enhanced academic achievement, creativity, and self-efficacy in STEM among girls, particularly in underrepresented and underserved regions. The study highlighted that the implementation of the Montessori STEM curriculum could drive educational equity, economic development, and social progress by nurturing the next generation of female innovators and leaders.

Article 8

Ashiat B. Muhammed, in the paper titled ***Digital Literacy of Senior School Chemistry Teachers in Nigeria: Challenges and Prospects,*** explored the evolving concept of digital literacy among Chemistry teachers in Nigeria, highlighting both its benefits and constraints. Initially, digital literacy referred primarily to the use of stand-alone computers, but with the advent of the internet

and social media, the focus shifted to mobile devices and navigating a complex digital world safely. The study employed secondary data drawn from reports, journals, and findings of other researchers to provide an overview of digital literacy and its benefits, such as flexibility, opportunities for collaboration, addressing the challenge of voluminous syllabi, and providing safer alternatives to hazardous practicals in Chemistry. The paper also outlined major constraints, including poor teachers' technological pedagogical content knowledge (TPACK), inadequate funding, poor power supply in the country, weak maintenance culture, and insecurity. Based on these findings, the study recommended that government should intensify efforts to expose science teachers to pre-service and in-service training through seminars and workshops, provide adequate funding for the procurement of digital gadgets, ensure regular power supply, improve maintenance culture, and secure digital resources.

Article 9

Innovative Pedagogy and Emerging Technologies in STEM Learning: Strategies, Platforms, and Educational Tools by Busayo O. Ogunronbi analyzed how the integration of innovative pedagogical strategies and emerging technologies is transforming STEM learning. The study examined the role of personalized learning platforms, as well as the incorporation of robotics and coding, in enhancing STEM education for both basic and post-basic learners. It highlighted the ways these tools foster engagement, promote problem-solving, and equip learners with 21st-century skills, thereby strengthening the effectiveness and relevance of STEM education in contemporary contexts.

Article 10

Bimerew Kerie Tesfaw, Mulugeta Atnafu Ayele, and Tadele Ejigu Wondimuneh, in the study titled ***Effect of Context-Based Problem-Posing and Solving Instructional Approaches on Students' Problem-Posing Skills in Learning Data Handling,*** **investigated** how context-based instructional approaches influenced fifth-grade students' ability to pose problems in data handling. The study was motivated by poor student performance and the limitations of traditional instructional approaches in mathematics, which hinder the development of 21st-century skills. A concurrent embedded quasi-experimental non-equivalent pre-test–post-test control group mixed-methods design was employed, involving 138 fifth-grade students. Data were collected using problem-posing skills tests, lesson observations, and semi-structured interviews. Quantitative data were analyzed using descriptive statistics, paired sample t-tests, and ANCOVA, while qualitative data were analyzed thematically. The findings showed that context-based problem-posing and solving instructional approaches significantly outperformed traditional teaching methods in enhancing students' problem-posing skills, with a medium effect size on post-total data handling and post-context-type data handling problem-posing skills. Students were found to develop their problem-posing skills through engaging with challenging topics, comprehending relationships, reading and interpreting images and graphs, organizing data, and changing, interchanging, and comparing

values. The study concluded that context-based approaches were effective in improving students' problem-posing abilities and discussed the implications for mathematics instruction and directions for future research.

Article 11

Demystification of Quadratic Equation Using the Box Technique by Steve D. Oluwaniyi (PhD), Solomon G. Ojo (PhD), Sylvester O. Okwuoza (PhD), and Florence O. Ale (PhD) highlighted the role of the Quadratic Equation Box (QEB) as an innovative tool for teaching and learning quadratic equations under school Algebra. Quadratic equations and expressions were noted as critical topics, often approached through completing the square, the quadratic formula, graphical, and factorization methods. However, students commonly experienced misconceptions about factorization and expansion. The QEB was introduced as a practical approach that enabled students to handle the factorization of quadratic expressions with greater ease. The study emphasized that the use of QEB enhanced retention, fostered originality, and contributed positively to the cognitive development of learners while demonstrating that even abstract Algebra could be taught and learned in a practical, engaging manner.

Article 12

Debrah Mulenga Mwango and Anecetus Moonga, in the paper titled ***Exploring STEM Outreach Activities through Libraries: A Case of Lusaka District Chapter,*** investigated the role of libraries in promoting Science, Technology, Engineering, and Mathematics (STEM) outreach activities in Lusaka District, Zambia. The study was driven by the persistent shortage of qualified STEM professionals in the country, which continues to hinder economic growth and development. It sought to determine how libraries could bridge this gap through outreach activities, addressing the lack of comprehensive understanding of the current state of STEM initiatives in district libraries and ways they could be improved to enhance community engagement and STEM literacy. A mixed-methods approach was employed, combining surveys, interviews, and observations to collect data from 20 libraries and 30 stakeholders in the Lusaka District. The findings revealed that while libraries were offering some STEM-related activities, limited coordination and insufficient funding negatively affected their quality and overall impact. The study highlighted the importance of collaboration between libraries, schools, and community organizations to design and deliver effective STEM outreach programs. It concluded that libraries could play a critical role in advancing STEM education and literacy if adequately supported with resources and coordination. Recommendations included increasing funding, strengthening partnerships, and integrating technology-based initiatives to expand the reach and effectiveness of library-based STEM outreach activities.

Article 13

STEM Outreach Programs: Evaluating the Impact on Rural and Low-Income Communities by Philiph K. Saina analyzed the potential of AI-driven personalized learning systems in advancing gender equity within STEM education. The study employed a mixed-methods research design to examine how AI tools could enhance student engagement and address gender disparities by providing individualized learning experiences. Quantitative findings showed a significant increase in engagement and motivation among female students exposed to AI-driven interventions

compared to those taught through traditional methods. Qualitative feedback further indicated that AI systems were effective in identifying and responding to individual learning needs, thereby contributing to more equitable educational outcomes. Despite these benefits, the research also revealed that AI was not a standalone solution, as persistent structural and cultural challenges continued to influence gender imbalances in STEM fields. The study concluded that while AI tools offered promising enhancements to personalized learning, their effectiveness depended on integration with broader educational reforms and systemic changes. It recommended that combining AI technologies with other gender-equity initiatives could lead to more comprehensive improvements in STEM education. The study also emphasized the need for further research into inclusive AI models, the long-term effects of AI on career trajectories, and the integration of AI with other educational practices to promote gender equity and improve outcomes.

Article 14

Katherine K. Zira, Khadijah Adamu, and Habiba Mohammed, in the research study titled ***Technology-Based Apprenticeship Training as a Panacea for Economic Empowerment of the Girl-Child,*** explored how apprenticeship-based vocational training (ABVT) could serve as a viable strategy for improving the economic empowerment of adolescent girls in Kaduna State, Nigeria. The study was grounded in the understanding that gender roles, expectations, and inequalities strongly influence access to resources, opportunities, and economic prosperity, while empowering women economically contributes to societal resilience and inclusive development. The project, funded by the Center for Girls' Education, focused on providing theoretical instruction combined with practical on-the-job training to out-of-school and dropout girls in six rural and peri-urban communities Kabama, Dumuga, Kayaba, Wuciciri, Samaru, and Zango—across three local government areas: Kudan, Sabon Gari, and Zaria. A total of 123 vulnerable girls between the ages of 14–19 years were recruited in two cohorts. The first cohort was trained in tailoring and ICT by experts for two years, while the second cohort was trained by the first cohort under expert supervision, creating a peer-led extension of the program. The apprenticeship incorporated multiple hands-on methodologies including watching, imitating, practicing, receiving feedback, teaching peers, solving real-world problems, and engaging in inquiry-based learning. Financial literacy sessions complemented the technical training, equipping the girls with knowledge of profits, savings, banking, loans, and investment. Out of the 123 girls, 109 completed the program, with 96% demonstrating the ability to work independently while 4% still required some supervision. The study concluded that girls across the targeted communities were economically empowered, and recommended that government and philanthropists support the scaling up of such programs through additional funding to ensure broader impact on vulnerable girls' economic independence.

Article 15

Quality Assurance as a Tool for Full Implementation of STEM Curriculum in Nigeria: A Case Study on Selected Schools in Police Force Education Unit in Relation to the Application of ASEI-PDSI Approach by Alh. Idris Danmusa emphasized **the** importance of quality assurance in ensuring the effective implementation of the STEM curriculum within Nigerian schools. The paper argued that the growth and development of any nation depended heavily on its educational philosophy, goals, and objectives, with policy formulation, implementation, and evaluation playing central roles in determining success. Within this context, the Nigerian education system was described as requiring a curriculum focused on Science, Mathematics, Engineering, and Technology across all levels of learning. The study highlighted quality assurance as a critical tool in realizing this vision, using selected schools under the Police Force Education Unit as a case study to evaluate the application of the ASEI-PDSI approach. The STEM curriculum was positioned as a transformative instrument, promoting learner-centered and practical-based approaches to teaching and learning, while ASEI-PDSI was identified as a vital principle for enhancing teaching practices and achieving improved outcomes. Recommendations included continuous collaboration between the Police Force Education Unit, the Universal Basic Education Commission (UBEC), and the National Teachers' Institute (NTI) to improve educational services; training and retraining of teachers for efficiency in delivering STEM content; provision of standard laboratories and equipment; and improvement of teachers' welfare and incentives. The paper concluded that enhanced quality assurance operations, including regular inspection and supervision of schools, were essential for quality control and for sustaining the effective implementation of the STEM curriculum in Nigeria.

Article 16

Chipo Namakau Sakala and Benson Banda, in the article entitled ***Assessing the Assessors: Exploring Zambian Teachers' Perceptions of School-Based Assessment (SBA),*** **explored** the perceptions of Zambian teachers regarding SBA implementation. School-Based Assessment was described as a key element of modern educational practices aimed at enhancing learning and offering a comprehensive evaluation of learners' capabilities. The study employed a longitudinal descriptive qualitative design with a mixed-methods approach. Data was drawn from an online collegial platform with 9.4k followers, focusing on 475 comments collected from various prompts posted over several years (2021, 2022, and 2023). The data was analyzed thematically and supplemented with descriptive statistics. The findings revealed significant concerns, particularly about increased workload, with many teachers expressing that SBA was not fulfilling its intended purpose and recommending its abolition. Specifically, 44 comments supported abolishing SBA. There was also considerable frustration about the non-inclusion of SBA marks in final grades, especially at the primary level, with 127 comments highlighting this issue. Although positive feedback was minimal, some teachers recognized SBA as a potential avenue for competence development. The implications of this study suggested that while SBA had potential benefits, its current implementation was fraught with challenges. This indicated the necessity for a comprehensive policy review and enhanced support systems, including professional development.

Policymakers were urged to consider these insights to refine SBA practices, ensuring they contributed meaningfully to educational outcomes. Recommendations included providing targeted professional development for teachers, integrating SBA marks into final assessments, and using the developed guidelines to support effective SBA implementation.

Article 1

Enhancing Learners Academic Achievement through Hands-on Learning: An Exploratory Study on Factors, Prime Factors, and HCF of Numbers among Basic Education Learners at National Teachers Institute (NTI) Demonstration School, Rigachikun, Kaduna Nigeria

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Abstract

The role of innovative hands-on learning in teaching and learning mathematics cannot be over-emphasized. Continuous efforts have been made by teachers and educators to explore more innovative teaching techniques and investigate their effectiveness and efficiency to enhance the teaching and learning of mathematics. This study investigated the impact of hands-on learning on the academic achievement of Basic Education 1 in understanding Factors, Prime Factors, and Highest Common Factors (HCF) of Numbers at the National Teachers Institute Demonstration School Rigachikun, Kaduna-Nigeria. A quasi-experimental design was employed, involving 60 Basic Education l randomly assigned to experimental and control groups. Two research questions were raised and answered using mean and standard deviation, and two null hypotheses were formulated and tested at 0.05 level of significance. Mathematics Achievement Test (MAT) was developed by the researcher and validated by two experts in measurement and evaluation. The experimental group received hands-on instruction, while the control group received traditional instruction. The instruments used for data collection was pre and post-test on factors, prime numbers and HCF of numbers. Results showed significant differences in the academic achievement of learners in the experimental group, with a higher score, compared to that of control group. The study suggests that integrating simulations enhances learners' understanding of mathematical concepts, improves engagement, and fosters deeper learning. The findings have

implications for mathematics education, highlighting the potential of hands-on learning to improve academic achievement among Basic Education learners in Nigeria.

Keywords: Hand-on learning, factors, prime factors, HCF, academic achievement, basic education 1 learners, and mathematics education.

1. Introduction

Mathematics is all around us and it is used by every human being either consciously or unconsciously in various aspects of our everyday life. Mathematics forms the basic tool for industrialization and national development of every nation. It is a key subject in both basic and post basic curricula because it provides learners an opportunity to develop critical thinking and logical judgment. It is also recognized to play a vital role in contemporary society, making it indispensable for the existence of any nation (Asante, 2010). The importance of mathematics to man has accounted for its inclusion in school curriculum as a compulsory subject for every child of school age to acquire the appropriate mathematical skills that will enable him/her cope with life challenges. With regards to this, mathematics should be taught as a core subject to all learners at basic and post basic level in order to give a sound basis for scientific and reflective thinking, and prepare them for the next level of education. The importance of mathematics does not only lie in its contributions to scientific and technological development but also in its utility in day-to-day interactions at the market places, transportations, business of all sorts by both literate and illiterate members of the society (Golji & Dangpe, 2016). Mefor, (2014) summarized it all by saving that mathematics relates to everything in the universe from the smallest to the largest. Therefore, mathematics is a subject that education and human life cannot function effectively without it. However, learners in our basic and post basic schools experiences difficulties with the learning of some concepts of the mathematics curriculum because the subject is taught in such a way that the mathematical concepts are largely removed from the everyday life of the learners and real world applications (CEMASTEA, 2013). Understanding of mathematical concepts forms the basic foundation for its application in the day-to-day activities.

The methods used by teachers to provide conditions in which learners can learn concepts of mathematics matters a lot, because it is the key for ensuring good understanding and application of the learned concepts. In this regard, continuous efforts should be made by teachers and educators to explore more innovative teaching techniques that are learner-centred and investigate how effective and efficient they are to enhance academic achievements of learners. Therefore, there is need for learners to be supported to gain an in-depth understanding of mathematical concepts for the appropriate application. To encourage and enhance learners' conceptual understanding, teachers need to be creative by using innovative explorations to create dynamic instructional strategies that are activity-based/learner-centred approaches.

The greater part of classroom activities are completed by traditional method generally. The learners sit silently in rows in the classrooms, the teacher does all the speaking and the learners inactively listen to the teacher. They talk just when approached and do just as they are told. In a conventional classroom, the learning abilities of majority of the learners are restricted only to duplicate what is written on the board and they are not capable of effectively handling the information through thoughts, evaluation and investigation. Because of this constrained intellectual capability, learners lose interest in learning. Hans-on learning is a strategy focused on the idea that learners ought to be included through activities. Hans-on learning is a method adopted by a teacher to emphasize his or her technique of teaching through action in which the learners take interest comprehensively and realize effective learning outcomes. It is the procedure in which the learner is effectively included in taking interest rationally and physically. Hans-on learning is an activity-based/learner-centred learning and interpreted as meaningful school learning settings in which the learner creates mathematical ideas through dynamic contribution. This procedure may include the control of physical materials, the usage of games, or participating in experimentations with physical items.

The use of traditional teacher-centered approaches in mathematics has been recognized as none inceptively for many learners. However, researchers have found that mathematics classrooms and the individualistic nature of mathematics, whereby learners work independently, actually discourages learning. Therefore, improving learner enjoyment of mathematics is a key strategy to address the subject disengagement. Innovative teaching methods that provide positive mathematical learning experiences could help to enhance learners' achievement in mathematics (Riley et al., 2017). However, most of teachers who conduct the teaching process may prefer to use traditional teaching methods which are still habits due to the crowded classes, limited time, material inadequacy and inadequate facilities.

The over reliance of this traditional approach in teaching in our schools encourage memorization of facts and concepts without actually exposing the learners to challenges that will make them actively engage in the learning process. Learners seem to learn very little and found learning to be difficult, boring and not interesting. The imperative role of mathematics notwithstanding, Mathematics is one of the most poorly taught, widely hated, and abysmally understood subjects in our schools (Ali, et al., 2010). This has always led to poor academic achievement and has been a great thing of worry for all stakeholders, such as parents, teachers, educational psychologists, counselors, government, and society at large. Therefore, there is a need for a paradigm shift to using innovative strategies that are appropriate, relevant, and effective to the teaching and learning the subject. Mvula (2020) opined that when appropriate learning methods are used, the learners develop proper attitudes and skills during the learning process. Hence there is a need to change from the conventional way of teaching Mathematics to effective ones. It is therefore, imperative

to search for more effective and innovative approach to teaching based on learner-centred approach (Constructivism). The results of this study will provide useful insights to the mathematics teachers, educators, school managements, and general public respectively on the differential effectiveness of hands-on learning on learners' academic achievement in mathematics. Also, academicians and scholars will use the study as a source of information regarding the effective learning of mathematics. Effective utilization of hands-on learning can make the teaching and learning of mathematics further successful. Keeping this perspective in view the researchers have attempted to work on "finding the impact of hands-on learning on the academic achievement of basic one learners in understanding factors, prime factors, and Highest Common Factors (HCF) of numbers at the National Teachers Institute Demonstration School Rigachikun, Kaduna-Nigeria." Finally, the study will add value to the literature on methods of enhancing the learning of mathematics among learners in our schools.

1.1 Research Questions

1. What are the learners' achievement scores on factors, prime factors, and Highest Common Factors (HCF) of numbers before exposure to hands-on learning and conventional method in National Teachers Institute Demonstration School Rigachikun, Kaduna-Nigeria?
2. What is the impact of Hands-on learning on the mean achievement scores of learners taught factors, prime factors, and Highest Common Factors (HCF) of numbers and those taught using conventional method in National Teachers Institute Demonstration School Rigachikun, Kaduna-Nigeria?

1.2 Null Hypotheses

The following hypotheses were formulated to guide the study and tested at 0.05 level of significant.

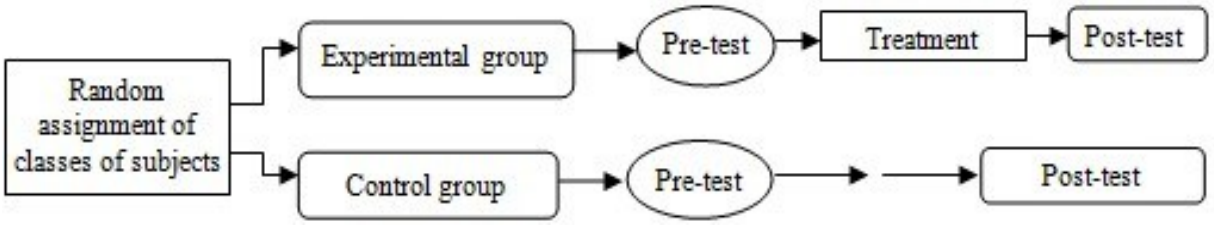
Ho_1: There is no significant difference in the achievement scores of the learners of control group and experimental group in the pre-test.

Ho_2: There is no significant difference in the achievement scores of the students taught factors, prime factors, and Highest Common Factors (HCF) of numbers using hands-on learning and those taught using conventional lecture method in the post-test.

2. Methodology

The study adopted Quassi-experimental research design. The sample for the study consists of sixty (60) basic education 1 learners randomly assigned to two different classes, the experimental and control groups in the National Teachers Institute Demonstration School Rigachikun, Kaduna-Nigeria. Then, the two groups were exposed to a pre-test to establish if they differ significantly before being exposed to the study. The instrument for data collection was Mathematics Achievement Test (MAT) developed by the researchers to test the learners' knowledge,

competencies and skills on the selected mathematical concepts. The instrument was validated by the senior colleagues in the departments of Academic Services and Examination of the National Teachers' Institute, Kaduna Nigeria. The control group was taught using the normal classroom practices that had been used before the start of this study and the teacher of this group was told on the need to adopt the hands-on learning activities in their teaching. The experimental group further undergoes treatment through the hands-on learning activities. Both the groups were then given a post-test for comparison purposes among them. See Figure 2 below:



Source: Adopted from Patidar (2013)

2.1 Experimental procedure

Prior to the treatment, a pre-test was administered to all the learners in the two groups to determine the ability levels of both experimental and control groups in factors, prime factors, and Highest Common Factors (HCF) of numbers. After that, the experimental group was taught the concepts using hands-on learning activities (bottle tops arrangements) for 2 weeks while the control group was taught same concept using conventional lecture method. At the end of the treatment, a post-test was administered to both the two groups (Experimental and Control)

2.2 Pre-Treatment Activities

The researcher administered a pre-test to confirm the entry level of both experimental and control groups in factors, prime factors, and Highest Common Factors (HCF) of numbers.

2.2.1 Treatment activities

Treatment after using the pre-test to ascertain the impact of hands-on learning on learners' academic achievement on factors, prime factors, and Highest Common Factors (HCF) of numbers, and the following activities were conducted as treatments.

3. Exploring the Concept of Prime Factor and HCF of numbers using bottle tops

Discuss the relationship the following numbers have with the number of bottle tops given to you: 1, 2, 3, 4, 6 and 12.

3.1 First let us start with counting the bottle tops in 1s, 2s, 3s, 4s, 6s, and 12s

Activity 1: *Count the bottle tops in groups of 1s, 2s, 3s, 4s, 6s, and 12s. (In group)*

A) 1, 2, 3, 4, 6, and 12 can be used to count 12 bottle tops.

1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 = 12 (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12).
2 + 2 + 2 + 2 + 2 + 2 = 12 (2,4,6,8,10,12).
3 + 3 + 3 + 3 = 12 (3,6,9,12).
6 + 6 = 12 (6,12).
Lastly 12.

B) Also, we can use 1, 2, 3, 4, 6 and 12 to arrange 12 bottle tops in a rectangular form. Thus,

Observations

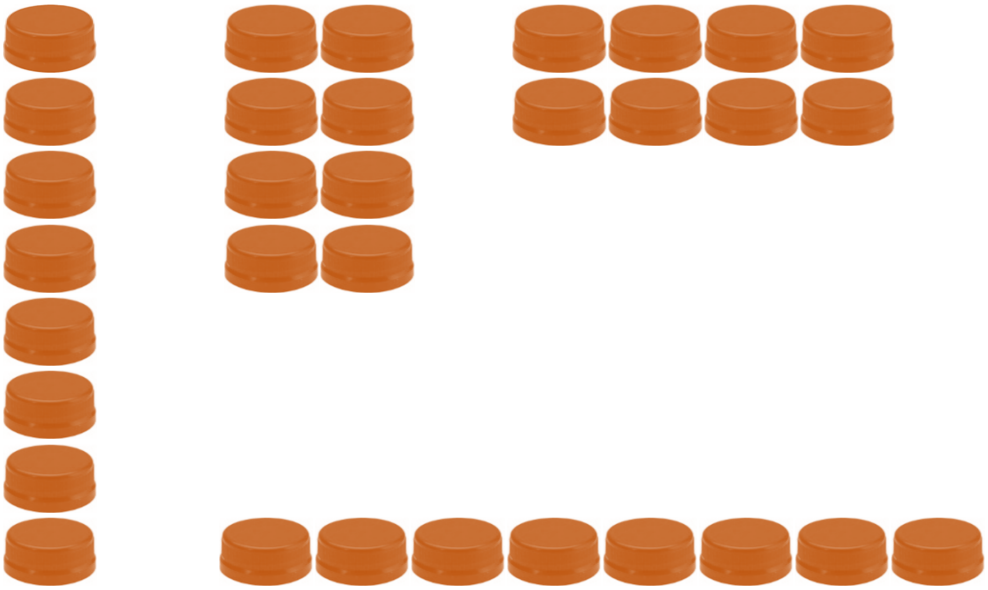
- From (A), observe that 12 bottle tops can be counted in groups of 1s, 2s, 3s, 4s, 6s, and 12s without leaving any bottle top as remainder. This implies that 1, 2, 3, 4, 6, and 12 are factors of 12.
- From (B), you can see that all these arrangements are forming rectangular arrays or

rectangular forms, from 1 row to 12 rows. It can also be reversed, which is from1 column to 12 columns.

3.2 Secondly let us look at various ways of arranging 8 bottle tops in a rectangular array

Activity 2: *Let's make Rectangles (In group)*
C) Arrange 8 bottle tops in all possible rectangular arrays (rectangular forms). Single straight lines, horizontal and vertical are also accepted. Record your observation on each rectangle you made.
D) Repeat the above using 7 bottle tops and then 20.

C)



D)

Observations

- From C, we can arrange 8 bottle tops in four different ways to form a rectangular array. This means that 8 have four factors and these factors are the number of rows in each arrangement.
- Similarly, 7 forms two arrangements while 20 six arrangements.
- Why is 7 having only two forms of arrangements?

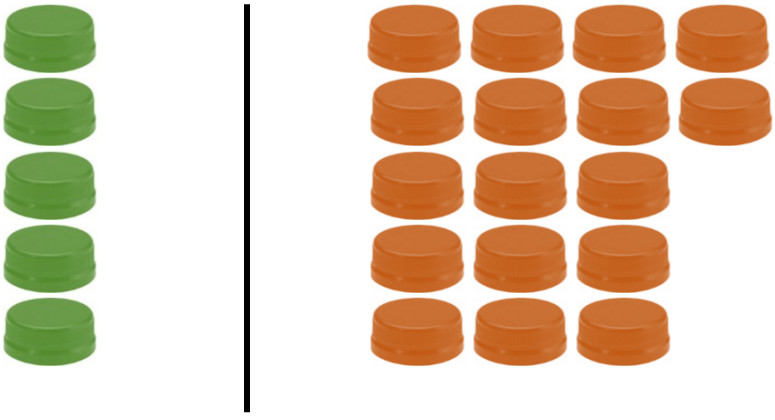
Note

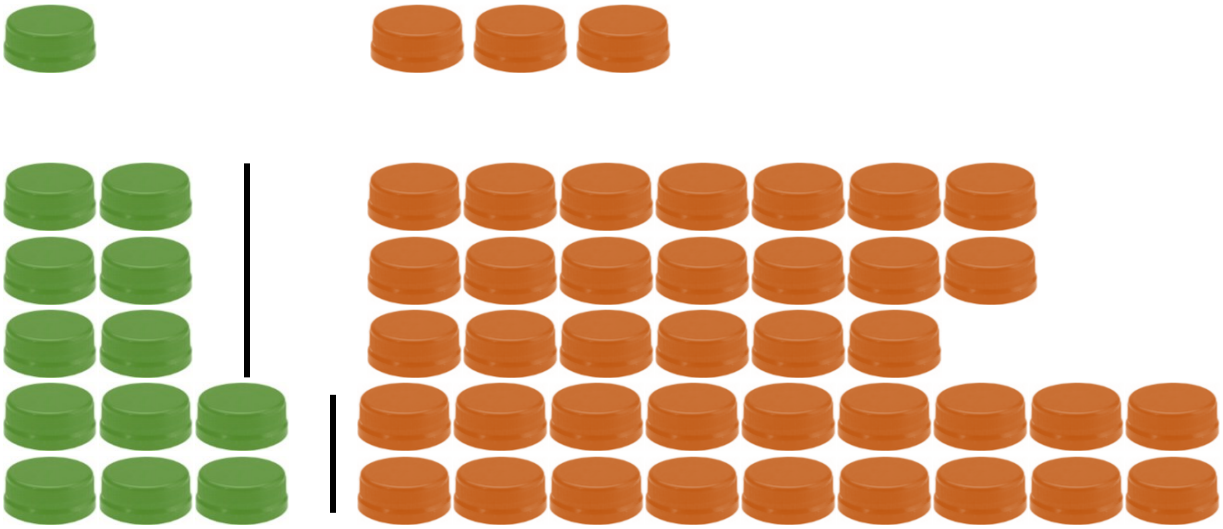
Number of rows gives factor if only arrange in a rectangular array (form).
Therefore, the number of rows in each arrangement above gives the factor of a given number of bottle tops.

3.3 Now, let us look Highest Common Factor (HCF) of 6 and 20

Activity 3: Let us find the HCF of 6 and 20

- Draw a straight line to divide a cardboard paper horizontally.
- Arrange 6 bottle tops in vertical line to the left half of the cardboard and then arrange 20 at the right half.
- What do you observe?
- Change the arrangement on the left to 3 rows of two bottle tops each and then change the arrangement of the 20 too on right. Do they form a rectangle?
- Change the arrangement on the left again into 2 rows of 3 bottles tops each, then change the arrangement of the 20 on the right. What do you observe?





Observations

- Observe that 6 and 20 bottle tops are arranged to form a rectangular array at the same time and both have two rows.
- Both form a rectangle only when we arrange into 2 rows because 2 is the HCF of 6 and 20.

Discussion on the activity

- By this simple bottle tops arrangements, learners can visualize the concept and idea of factors, HCF, prime factor and also multiplication.
- These series of activities illustrate the relationships of whole numbers and it lead to visualization which will help learners to gain deeper conceptual understanding of factors, HCF and prime number and it will help them to apply the concepts to solving problems.
- Similarly, this simple bottle tops arrangements can easily be devised to illustrate the concepts of multiple and Lowest Common Multiple of numbers.

3.4 Using Hands-on Learning to build Conceptual Understanding

Hands-on learning offer learners unique learning opportunities that paper and pencil tasks simply just can't. Have you ever had a learner be able to seamlessly recite multiplication facts, but unable to explain how it works and why it works that way? This learner lacks a conceptual understanding of multiplication. Conceptual understanding has become an essential component of best practice teaching since the Common Core was adopted, as it expects learners to do more than rote memorization. Instead, it demands that learners be active participants in real-world learning and application to prepare them for challenges of the twenty-first century and future challenges.

One way to build this conceptual understanding is through hands-on learning. Learning mathematical concepts and ideas using manipulatives and tools that give learners the hands-on learning experiences they need to make sense of these mathematical concepts and ideas through exploration and self-discovery.

3.4.1 What is Hands-on Learning?

The hands-on learning approach is the idea that learners need to feel and touch what they are their learning through a concrete learning experience before they are exposed to more of the abstract learning that takes place when learners solve equations. For example, before we introduce the standard algorithm for solving two-digit addition problems with regrouping, students must work with the base-ten blocks and go through the process of breaking the ten into ten ones to solve the problem.

3.4.2 Why is Hands-on Learning important in the Teaching and Learning of Mathematics?

Hands-on learning is important because it helps learners build conceptual understanding, which is one of the five strands the National Research Council identified as being an integral part of mathematics education. In addition, hands-on learning activities increase learner participation and engagement and also promote deeper understanding of the mathematical concepts and ideas.

3.4.3 What is Conceptual Understanding?

The National Research Council identified five strands that define math proficiency in 2001: Conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. **Conceptual understanding**, one of the five strands, is the "comprehension of mathematical concepts, operations, and relationships" to the extent that learners can transfer and apply what they learn to new situations and contexts.

Conceptual Understanding is:

- Understanding why we are learning about a concept or skill
- Applying prior learning to a new situation
- Explaining and justifying
- Reasoning
- Comparing and contrasting mathematical concepts
- Generating new ideas
- Thinking flexibly
- Utilizing models and manipulatives

Conceptual Understanding is not:

- Simply being fluent in procedures and facts

- Rote memorization

3.4.5 What differentiates Conceptual Understanding from Procedural Fluency?

Prior to 2001, the emphasis in mathematics instruction was on procedural fluency, which was referred to as procedural knowledge at the time. **Procedural fluency** in mathematics is the ability to follow a sequence of steps "flexibly, accurately, efficiently, and appropriately." Learners were expected to learn procedures (procedural fluency), like how to regroup, but were not necessarily expected to have a deep understanding (conceptual understanding), like why they are regrouping and what it means.

In recent years, recommendations of effective mathematics instruction have transitioned to a more balanced approach to learning. Conceptual understanding and procedural fluency are equally important. They are both part of five strands that define mathematics proficiency according to the National Research Council. As a result, it is essential for teachers and educators to support learners in developing both abilities.

3.4.6 Why is Conceptual Understanding Important in Learning Mathematics?

Conceptual understanding in mathematics is important because it:

1. Prepares learners to solve problems in the real world
2. Equips learners with the ability to make connections and solve more complex mathematics problems
3. Gives learners the higher order thinking skills needed to deeply understand and transfer knowledge to new situations
4. Supplies learners with a strong number sense and mathematical foundation
5. Develops learners into individuals who are proficient in mathematics

3.4.7 Ways to build Conceptual Understanding in Mathematics

Here are some ways to begin building conceptual understanding in mathematics in your classroom:

1. Use mathematics manipulative and pictures to teach concepts, solve problems, and explain thinking.
2. Create opportunities to discuss mathematics concepts and strategies with peers and the teacher through number talk.
3. Represent and solve problems in different ways through modeling and celebrate when learners do the same.
4. Solve real-world mathematics problems using models.
5. Supply your learners with mathematics tool kits that they can access independently and use as needed. These resources can elevate a worksheet task into a hands-on mathematics learning experience.

3.5 Method of Data Analysis

Data collected were analyzed using mean, standard deviation and t-test statistical tools.

Hypothesis One: There is no significant difference in the achievement scores of the learners of control group and experimental group in the pre-test.

Independent t-test statistics on difference in the pre-test's mean achievement scores of experimental and control groups.

Table 1

Group	N	Mean	SD	Df	α	t-cal	t-crit	Decision
Exp.	30	10.62	3.19	58	0.05	0.65	1.68	Retained
Cont.	30	10.60	3.25					

It can be shown in Table 1 that the pre-test's mean achievement scores of experimental and control groups finds not significant having the t-calculated value of 0.65 is less than the t-critical value set at 0.05 level of significance. The null-hypothesis is thus retained because there was no significant difference in the pre-test mean academic achievement scores of experimental and control groups of mathematics learners of Basic Education 1 at National Teachers Institute Demonstration School Rigachikun, Kaduna-Nigeria. This means that the result of their entry level of mastery and skills in solving problems on Factors, Prime Factors, and Highest Common Factors (HCF) of Numbers before exposing to the two was almost the same.

Hypothesis Two: There is no significant difference in the achievement scores of the learners of control group and experimental group in the post-test.

Independent t-test statistics on difference in the mean achievement scores of learners in experimental and control groups

Table 2

Group	N	Mean	SD	Df	α	t-cal	t-crit	Decision
Exp.	30	17.87	4.63	58	0.05	11.65	1.68	Rejected
Cont.	30	14.80	3.57					

It can be shown in Table 2 that the post-test mean achievement scores of learners in experimental and control groups finds significant having the t-calculated value of 11.65 is greater than the t-critical of 1.96 value set at 0.05 level of significance. This means that the result the null-hypothesis

is thus rejected because there was significant difference in the post-test mean achievement scores of experimental and control groups of mathematics learners of National Teachers Institute Demonstration School Rigachikun, Kaduna-Nigeria. The academic achievement level of learners of experimental group who were exposed to hands-on learning activities is higher than compared to those of the control group.

4. Discussion of result

The result in table 1 give answer to research question one and the analysis of independent t-test of the hypothesis one.

The findings showed that learners taught factors, prime numbers and HCF of numbers in the experimental group had 10.62 and the control group 10.60 indicated no significant difference in students' pre-test achievement scores. This result shows that learners in both control and experimental groups have same ability in factors, prime numbers and HCF of numbers. This may be due to the fact that both classes use the same curriculum, teaching method and they are taken by the same teacher.

The result presented in table 2 revealed answers to research question two and the analysis of independent t-test of hypothesis two. The result indicated that there was significant difference in the academic achievement scores of learners taught factors, prime numbers and HCF of numbers using hands-on learning activities (bottle tops arrangements) and those taught with conventional teaching method. This implies that the use of hands-on learning activities have significant impact on the achievement scores of learners in mathematics. It therefore showed that the bottle top activity has provided the learners with conceptual understanding of factors, prime numbers and HCF of numbers. This showed that using hands-on learning activity in teaching and learning of mathematics helps in improving learners' achievement immensely. This result agrees with the findings of other research where activity based learning and conventional learning were compared in terms of impacts on students' achievement. This result agreed with Magno et al. (2005) who concluded that students who received instruction through activity method had significantly higher performance in tests than those who receive instruction through the conventional method. The result obtained is in line with the findings of Adedoyin (2010), Damole, Femi & Adoye (2004), whose findings reveals that instructional approaches that involves active participation of students would be effective.

The finding also agreed with the finding of Batdi (2014), who pointed out that the activity-based teaching and learning had positive impact on students' academic achievement. Additionally, the finding agreed with the finding of (Celik 2018; Camaci 2012). These studies investigate the impact of activity-based teaching and learning of mathematics on students' achievement. The concluded that activity-based learning strategy increases academic success. It was also concluded that, if teaching and learning were based on activities that actively engaged learners, the topics or concepts of the learning were grasped better Rubin et al. (2014), teaching enriched with activities affect

student perceptions positively (Kostereliogluand Yapici, 2016).

5. Conclusion

On the basis of the findings of this study, it can be concluded that the use of hands-on learning activity is an effective strategy in enhancing learners' conceptual understanding and academic achievement in learning the concepts of factors, prime numbers and HCF of numbers than the conventional lecture method of teaching, because it boosts the academic achievement of learners in National Teachers Institute Demonstration School Rigachikun, Kaduna-Nigeria.

6. Recommendations

Based on the findings from this study, the researchers recommended that:

1. Teachers should practice hands-on learning approach because it is effective in the teaching and learning mathematical concepts.
2. Further study should be carried out to investigate the impact of hands-on learning (bottle tops arrangements) on learners' academic achievement to provide database for researchers and educators.
3. Expanding the sample population, time of intervention or investigating and introduction of another dependent variable are potential points for future studies.
4. Conferences and workshops should be organized to mathematics teachers on the use of hands-on learning activity in the teaching and learning of mathematical concepts.

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Article 2

Animated- Cartoons Aided Instructional Package and Pupils' Achievement in Mathematics

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Abstract

The study investigated animated- cartoons aided instructional package and pupils' achievement in Mathematics in Ekiti State primary schools. The study adopted pre-test, post-test, control group quasi- experimental design. The population for the study comprised 18, 215 primary school pupils (Pry II) in 911 Public Primary Schools in Ekiti State, (Ekiti State Universal Basic Education Board, 2023). The sample for the study consisted 74 Pry II pupils. The study adopted a multi - stage sampling procedure. The instrument for the study was Mathematics Achievement Test (MAT). The instrument was subjected to scrutiny by experts in Mathematics Education for face and content validity. The reliability of the instrument was done by using test re-test method. The instrument was administered twice within an interval of two weeks on 20 primary II pupils in public primary schools outside the actual sample. Their scores were analyzed using Pearson's Product Moment Correlation Analysis which yielded reliability coefficient of 0.85. The experimental procedure of the study was in four stages. The data collected were analyzed using descriptive and inferential statistics. The findings of the study showed that the use of animated- cartoons aided instructional package was effective in Mathematics in primary schools. However, there was significant difference in the post-test mean scores of pupils in the experimental and control groups. It was further revealed that retention level of pupils taught Mathematics using animated-cartoons aided instructional package was high in primary schools. The finding of the study revealed that there is no significant difference in the mean scores of pupils exposed to animated- cartoons aided instructional package in Mathematics in primary schools on the basis of school location. Based on the findings, it was recommended that teachers should be trained on how to use animated-cartoons aided instructional package to improve pupils' retention in Mathematics in primary schools.

Keywords: *Animation, Cartoon, Instructional package, Achievement*

1. Introduction

Mathematics helps pupils to recognize the difference that exist between two or more numbers. Mathematics as a subject is relevant to all other subjects taught in schools today as it is a door for

pupils planning to gain admission into secondary and higher institution. The survival of technology, weather forecasting, banking, data processing, accounting, and medical among other fields, has been based on a solid understanding of Mathematics. With its dynamism and tentacles that spread across other disciplines, it is used to fix the right peg into the right hole by providing qualitative and quantitative techniques for planning, managerial decision- making skills and economics for every human to live a better life. (Oginni, 2013)

Pupils may solve simple number base problems using Mathematics, and develop these skills in school. Everyone needs Mathematics in their daily lives no matter the nature of their occupation. Mathematics teaches people to be systematic or methodical because it involves the application of knowledge; there are countless Mathematical patterns in the fabric of nature; and it develops certain skills such as the ability to reason, be creative, or think abstractly.

Nation's technological and scientific position could be assessed through its Mathematical prowess. Mathematics education helps to achieve the goals of broad human education. This explains why the government, specifically the Ministry of Education, had made Mathematics an important subject. According to Mathematics is a subject that requires logical reasoning and practice with numerical problems to help pupils learn concepts; yet, pupils must practice the problems repeatedly to fully grasp them and think effectively (Pearse& Walton, 2011).

Every pupil at the Primary levels of education offers Mathematics in order to continue their study. As a result, Mathematics serves as the foundational intellectual discipline of the modern society and the language of science, whose emphasis on scientific literacy has become a prerequisite for any country's technological advancement (Federal Ministry of Education, 2014). Mathematical applications and the development of contemporary society have garnered a greater public interest in our modern age of science and technology thereby giving it a more prominent position. It is crucial to the advancement of information and communication technology (ICT). Mathematics is more than just the science of numbers, is taught to pupils in the subject of Mathematics by teachers; it involves the nation's knowledge transmission and understanding of strange phenomena and it links them to other civilizations in order to advance the educational system.

In the opinion of Odeyemi (2022), the problems faced by Mathematics educators and pupils worldwide are summed up as follows: lack of teaching techniques, inadequate trained Mathematics instructors, teachers with degrees from other fields teaching Mathematics, a lack of understanding between the pupils and the subject, inadequate materials, inadequate classrooms, lack of confidence, fear and doubt, a low intelligent quotient, a short attention span, and a lack of understanding of signs and symbols, Some qualified Mathematics educators have administrative duties which prevent them from fulfilling their primary responsibility of teaching.

Poor methods of teaching seem to be one of the main causes of pupils' abysmal academic achievement in Mathematics. Instead of involving pupils in active learning, the approach to teaching Mathematics emphasizes memorization procedures and the distribution of rules. The inability to apply their Mathematical knowledge to solve problems on a daily basis result from lack of appropriate critical thinking habits. Because of this, neither autonomous work nor a general

lack of interest in the subject among the pupils' body makes for a tepid appearance in Mathematics classes. In a traditional classroom, the teacher is the sole source of instruction, and the pupils are solely restricted to listening. It is really challenging when pupils are not allowed to participate enough in regular classroom settings. Pupils spend a lot of time sketching, reading, and reading frequently, thus there are typically little chances for individualized attention or response. This approach to education has not succeeded in fostering true Mathematical knowledge and does not encourage independent study and pupil's engagement. In order to solve a specific problem, a pupil can use Mathematics to study and grasp Mathematical concepts (Samuelson, 2011). To hold the pupils' attention, the teacher must provide the information in an engaging manner.

For pupils to understand Mathematics, pupils must be familiar with the teaching strategies that will work best for each pupil. Therefore, teachers should concentrate on pedagogical strategies that could increase pupils' interest in Mathematics. This method of teaching could be viewed as the vehicle through which a message is delivered. Alieme and Monica (2015) acknowledge that it is important for Mathematics teachers to adopt different methods of teaching pupils at the end of each lesson that will be acceptable to the pupils. To impact knowledge, good teaching requires teachers to employ a variety of approaches and learning processes. In this study, the researcher intends to see how abstract Mathematics teaching could be depolarized.

Animated-cartoons aided instructional package is an educational technique which could be utilized to ease test anxiety, lower tension, improve the learning atmosphere, guarantee attention continuity, and attract pupils' attention. Cartoon and animated images are the same. The term "anima" in Yunani originates from the word for life and soul. It may also refer to giving an object life by stirring it at a precise time. Today, animated-cartoons have been a part of our lives since we were children). Using animated-cartoons to teach Mathematics should include all of the educational levels (Baykul, 2001). Developing of high -level skills in Mathematics is a useful activity and with the implementation of animated-cartoon in teaching Mathematics. Most of the animated cartoons are specially made to help pupils' achievement in Mathematics. These animated cartoons develop the pupils, add values of responsibility, fairness, trust, sharing, etc in them facilitate the learning of music and gymnastic moves and contribute to the teaching of concepts and development of other cognitive skills in them. Animated cartoons are the methods that can be used to support Mathematics teaching in class or outside the class. Animated-cartoons support teaching in constructive learning, contextual learning, social skills, collaborative learning and critical thinking (Ilhan &Certinkaya, 2013)

The use of animated-cartoons in teaching Mathematics in class also prevents pupils' destructive behaviours, ease boredom and increase the amount of interest and connection, thereby helping to build a positive learning location. Using animated cartoons in teaching Mathematics is a better medium of communication and therefore, it deserves to be studied. The language used is simple for learners or pupils to understand and it is useful for eliminating the contradictions between perception and reality because phenomena and events are generally exaggerated to succeed in

explaining action. Using animated-cartoons in teaching Mathematics in class encourages pupils to think seriously, attracts attention and decreases monotonousness of the subject. Through this, the teaching period can be made likeable, and therefore, the will to learn can be increased. It also increases the memorability of Mathematics and provides effective learning through colours and sounds.

A cartoon is a common tool with many vibrant colors that is primarily used for enjoyment. A cartoon can also be a little animated film, movie, or video. Science concepts are visually represented through concept cartoons. The straightforward illustrations present a variety of perspectives on scientific concepts in contexts that are intended to interest and inspire pupils and promote debate of the concepts. Pupils are the primary audience for cartoons. They are typically broadcast on television or published in newspapers and magazines. Cartoons were previously meant for the purpose of entertainment only but these days, cartoons are now being extensively used for other purposes as well. Cartoons are now being used for education and spreading of awareness amongst the people in addition to being a form of entertainment. Teaching is a very strenuous profession. Transferring one's knowledge from one's mind into another pupils' mind requires a lot of effort. This makes teaching more difficult and needs a lot of new tools, concepts, and tactics. The effectiveness of animated cartoons as a source of real audiovisual materials for arithmetic instruction has been established.

In order to motivate pupils' interest in Mathematics during the teaching and learning process, it has been found that animated cartoons, when used as a trustworthy and reliable source of information, are an effective teaching tool. A growing number of educators are using animated cartoons as a teaching tool to replace the conventional approach to teaching Mathematics. Cartoons help pupils learn more effectively and more efficiently because they breathe life into dry book pages and reveal obscure concepts. Cartoons draw a lot of attention. The cartoon visuals that children view leave an effect on their minds, and they often remember what they saw in cartoons or what actions the cartoons performed.

Animation is a method for transforming static images into moving ones. In a conventional animation, pictures are manually painted or sketched on cellulose sheets before being photographed and shown on films. The majority of animation created today uses computer-generated imagery (CGI). Animated educational movies encourage pupils to explore complicated facets of knowledge while also fostering their comprehension and creativity. Pupils' skill sets are improved through animated cartoons. As a result, this makes it possible for teachers to illustrate various concepts. Additionally, it is a playful approach to learning that encourages experimentation.

Animation refers to techniques of photographing successive drawing or positions of models. Animation describes the techniques used to photograph subsequent sketches or locations of models in order to replicate a moment when a film is shown in a sequence. A cartoon is a sketch, a television programme, or a film that employs animation techniques. Since there is no formal distinction between them and they frequently have subtle variations of the same thing, any technique that mimics the motion of the screen is regarded as animation.

Animated-cartoons as an attention - gaining strategy help to reduce the processing demands in science, technology and Mathematics (STM). In Mathematics, 'Aktas, Bulut and Yuksel (2011) report that academic performance of the pupils increased by using computer animation and activities about patterns. Instructors' creative approaches to the teaching of Mathematics could be influenced by the use of effective strategies at all educational levels in terms of impacting knowledge and skills to the pupils. To help one understand is therefore considered a modus operandi for effective problem solving. It is a method for solving problems where an expression is present, such as when trying to simplify an algebraic equation. According to Breen and O'Shea (2010), Mathematics thinking involves thinking, reasoning, abstraction, and specialisation, all of which help pupils progress.

Animated-cartoons makes it possible to include more complex visual demonstrations into the classroom in order to teach and clarify technical and abstract concepts and to provide pupils with a better option. Cartoons, which are described as humorous drawings, are most frequently found in newspapers as a form of social commitment. When a teacher uses humor and is able to make the pupils smile or laugh, then the teacher, at least, in part knows that the pupils have been engaged with their response, which is one form of feedback to the teacher. It is essential to have a strong library of appropriate animated cartoons, which can be accumulated over time. Once they are aware of the package, pupils frequently lend a hand by finding the right examples—or a number of them. According to the study, using animated cartoons as a teaching technique can make Mathematics lessons more engaging and help pupils develop critical thinking skills.

2. Methodology

This study adopted pre-test, post-test, control group quasi-experimental design (one experimental group and one control group). The population for the study consisted of 18,215 Primary School pupils (Pry II) in public schools in Ekiti State (State Universal Basic Education Board 2023). The sample for this study consisted 74 primary II pupils selected from four public primary schools. The selection was based on multi stage sampling procedure. The instrument for this study was Mathematics Achievement Test (MAT). The instrument was subjected to scrutiny by experts in the Department of Science Education and experienced Mathematics teachers for face and content validity. The reliability of the instrument was done by using test- re-test method. The instrument was administered twice on 20 primary II pupils in the public primary schools outside the actual sample used for the study for two weeks. Their scores were correlated by using Pearson's Product Moment Correlation Analysis which yielded reliability coefficient of 0.85. This was adjudged high enough to consider the instrument reliable. The experimental procedure for this study was in three stages, namely: the pre-treatment stage, treatment stage and post-treatment stage. The data generated from the instrument was analysed using descriptive and inferential statistics. The research questions were answered using mean and standard deviation. The hypotheses formulated were tested using t-test. All the hypotheses were tested at 0.05 level of significance.

Testing of Hypotheses

Hypothesis 1: There is no significant difference in the pre-test mean scores of pupils in the experimental and control group.

Table 4: *t-test Analysis of Pre-test Mean Scores of Pupils in Experimental and Control Groups*

Sources of Variations	N	Mean	SD	df	t_{cal}	P-value
experimental	36	7.861	2.63	72	1.391	0.169
control	38	8.789	3.10			

P>0.05

Table 4 shows that the t-cal value of 1.391is not significant because the P-value (0.169) >0.05. This implies that null hypothesis is not rejected. Hence, there is no significant difference in the pre-test mean scores of pupils in the experimental and control group. This implies that pupils in both groups were homogenous before the treatment. Therefore, any change that occurs thereafter is as a result of the treatment given.

Hypothesis 2: There is no significant difference in the post-test mean scores of pupils in the experimental and control group

Table 5: *t-test Analysis of post-test Mean Scores of Pupils in Experimental and Control Groups*

Sources of Variations	N	Mean	SD	df	t_{cal}	P-value
experimental	36	25.361	2.789	72	21.018	0.000
control	38	10.842	3.149			

P<0.05

Table 5 shows that the t-cal value of 21.018 is significant because the P-value (0.000) <0.05. This implies that null hypothesis is rejected. Hence, there is significant difference in the post-test mean scores of pupils in the experimental and control groups. The mean scores showed a significant difference of 14.519 in favour of pupils in experimental group and this implies that animated-cartoons aided instructional package was effective for teaching of Mathematics in primary schools.

Hypothesis 3: There is no significant difference in the performance mean scores of male and female pupils exposed to animated-cartoon aided instructional package.

Table 7: *t-test Analysis of Male and Female Pupils Exposed to Animated-cartoons Aided Instructional Package*

Sources of Variations	N	Mean	SD	df	t_{cal}	P-value
Male	16	26.333	2.609	34	1.820	0.078
Female	20	24.650	2.833			

P>0.05

Table 7 shows that the t-cal value of 1.820 is not significant because the P-value (0.078) > 0.05. This implies that the null hypothesis is not rejected. Hence, there is no significant difference in the mean scores of male and female pupils exposed to animated-cartoons aided instructional package

in Mathematics in primary schools. This implies that the treatment had the same effect on both male and female pupils in Mathematics in primary schools.

3. Discussion, Conclusion and Recommendations

The findings of the study revealed that the use of animated-cartoons aided instructional package was effective for teaching Mathematics in primary schools. The findings agreed with the finding of Munir (2016) that the use of cartoons in science instruction has allowed for the successful evocation of prior information, conceptual growth, and multiple methods of learning scientific concepts. The findings also agreed with the work of Bada (2012) that animated-cartoon films enable pupils to function at a higher level and provide more information that could bring about Mathematics enjoyment. The findings of the study revealed that there is significant difference in the post-test mean scores of pupils in the experimental and control groups. This implies that animated-cartoon aided instructional package was effective for teaching of Mathematics in primary schools. The finding is in agreement with the work of Aktas, Bulut and Yuksel (2011) that academic performance of the pupils increased by using computer animation and activity patterns. The findings of the study revealed that the treatment had the same effect on both male and female pupils in Mathematics in primary schools. The finding concurs with the finding of Maikanno (2007) that gender of pupils is one aspect that affects their comprehension of Mathematics. The findings disagreed with the findings of Popoola (2013) that girls often score worse than boys on average, although secondary school Mathematics performance in Nigeria has recently been generally dismal. The findings implies that other factors aside gender could influence pupils' performance in Mathematics in primary schools. The study concluded that animated-cartoons aided instructional package was effective for teaching Mathematics in primary schools. The use of animated-cartoons aided instructional package brought significant improvement to both performance and retention of primary schools in Mathematics. The package is gender insensitive. Based on the findings of the study, the following recommendations were made: Primary school teachers should be trained on how to effectively use animated-cartoons aided instructional package to improve pupils' performance and retention in Mathematics

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Article 3

Integrating Aquaculture into Stem Curriculum: Evaluating Water Quality, Growth Performance, Nutrient Utilization, and Survival of *Clarias Gariepinus* (Burchell, 1822) Juveniles at Different Stocking Densities in Plastic Bowls

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Abstract

This study evaluated the effects of stocking density on water quality, growth performance, nutrient utilization, and survival of African Catfish (*Clarias gariepinus*) juveniles reared in plastic bowls, with a focus on integrating aquaculture into the STEM curriculum. Overstocking increases stress, leading to higher energy requirements and reduced growth rates and food utilization. Groups of 225 fish were stocked at densities of 5, 10, 15, 20, and 25 fish per bowl in triplicate. Initial mean weights ranged from 9.27 to 10.30 grams. Over a 56-day trial (April to June), fish were fed 5% of their body weight twice daily. Final mean weights for densities of 5, 10, 15, 20, and 25 were 79.08, 86.65, 75.60, 74.08, and 85.24 grams, respectively. Water parameters monitored included temperatures from 22.9°C to 30.9°C, pH from 6.6 to 7.0, and dissolved oxygen levels from 2.5 mg/L to 6.5 mg/L. Statistical analysis revealed significant impacts of stocking density on all parameters, highlighting the role of aquaculture in STEM education. Lower stocking densities showed better growth and survival rates, underscoring the benefits of integrating aquaculture into STEM curricula to enhance learning and practical application of scientific principles. It is recommended that schools develop a structured curriculum incorporating aquaculture projects with clear learning objectives and assessment criteria.

Keywords: African Catfish, Aquaculture Systems, Growth Performance, Stocking Density, STEM Curriculum Integration

1. Introduction

The African Catfish (*Clarias gariepinus*) is many qualities which makes them suitable very popular within the aquaculture system in for culturing. They have a high fecundity, faster growth rate, disease resistance; can withstand hand stress as well as being highly palatable (El-Sayed, 2002). A review of world fisheries indicated that the contribution of aquaculture can only be realized if a number of issues including stocking density of aquaculture species are addressed (FAO, 1995).

The growth of *Clarias* species depends upon stocking density, dietary, protein quality, energy content of feed, physiological status (age, sex), environmental variables, farming conditions and food availability (Lovell, 1989). In terms of fish production in plastic containers, over-stocking (high stocking density) which is related to the volume of water or surface area per fish is an important factor. Increase in stocking density (overstocking) results in increasing stress, which leads to higher energy requirements, causing a reduction in growth rate and food utilization. Identifying the optimum stocking density for a species is a critical factor for designing an efficient culture system (Leatherland and Cho, 1985). Controlling the fish size and production are the two important tasks to meet the market demands as price of fish is determined by the market demand of supply (size and production) and that in turn depends on their growth rate. Raising fish at relatively high stocking densities maximizes the use of culture area and is an effective measure for improving farm profitability. However, growth performance, health status, and disease susceptibility are related to stress conditions caused by high density. One of the ways to increase the production and growth rate of *Clarias gariepinus* is through a reliable stocking density so that consumers and farmers can actualize their desired objectives which is usually growth for economical and profit maximization. Stocking density is thus an important parameter in fish culture operation, since it has a direct effect on the growth, survival and production (Alatise, 2006). Stocking density has also been found to be one of the principal factors in regulating aquatic behavior of *Clarias gariepinus*. Aggressiveness seems to increase at lower densities and decreases at higher ones in some species while others show greater levels of aggression and even cannibalism when stocking density increases (Otubusin, 1997).

Stocking density is one of the main factors determining the growth and the final biomass of *Clarias gariepinus*. Stocking density is often considered a chronic stressor, potentially leading to a suppression of stress responses. High stocking density can have positive or negative effects on fish growth and this interaction seems to be speciesspecific (Jørgensen *et al.*, 1993; Hosfeld *et al*., 2009; Salas-Leiton *et al.*, 2010; Tolussi *et al.*, 2010). Increased stocking density can alter immunological responses, as well as physiological and biochemical processes related to metabolism and behavior (Santos *et al.*, 2010).

Physicochemical Parameters of Water Interactions of physical and chemical properties of water contributed to the composition, distribution and abundance of aquatic organisms, it also gives an insight into the relationship between organisms and their environment and can be used to determine water quality and productivity of the water body (Haruna *et al.*, 2006). Physicochemical attributes of water would assist in discovering the design and function of the water environment to its living organisms. Availability of certain chemical elements in water may result in an effect on the biotic component of the water (Mustapha, 2003). Appropriate equilibrium of physical, chemical well as biological components of a water body is a vital requirement for a successful fish production and therefore occurrence or absence of a given element in an aquatic habitat can be a determining factor in the general productivity of that water body, it could also determine the category of living organisms that might be present in the water body (Mustapha *et al.*, 2005). Water with high quality is needed for the entire life of fish as it provides the necessary requirements for the welfare of fish such as reproduction, breathing, feeding and growth (Mustapha *et al.*, 2013).

Temperature is an important physical parameter in an aquatic environment because many biological and chemical processes are temperature dependent. It is one of the environmental conditions affecting fish growth and survival (Graynoth *et al.*, 2000, León *et al.*, 2006). Sudden increase in water temperature can result in an increase in respiratory metabolism and also increased maintenance strategy and rapid weight loss, but sometimes increase in temperature can increase fish feeding rate, digestion and feed conversion efficiency (Vu and Ueng, 2021). Dissolved oxygen (DO) is one of the most important indicators of water quality in any aquatic environment; a large proportion of aquatic organisms obtain oxygen directly from the water instead of gasping from the atmosphere (Faithful *et al*., 2005). Any reduction in dissolved oxygen level outside the optimum condition of a particular fish species would result in fish stress (Haruna *et al.*, 2006). Dissolved oxygen level and sometimes fish stocking density are among major prerequisites for a successful aquaculture development (Duan *et al.*, 2011). Dissolved oxygen content in water can affect fish growth pattern as well as feed utilization efficiency, lower fish growth rate correlated positively with lower dissolved oxygen concentration and fish feed conversion efficiency is higher under high dissolved oxygen concentration (Bergheim *et al.*, 2006; Duan *et al.*, 2011).

The pH of an aquatic ecosystem is important because it is closely linked to biological productivity, although the tolerance of individual species varies, pH values between 6.5 and 8.5 usually indicate good water quality (Wurts *et al.*, 1992). Very low and high pH levels may reduce reproduction in fish, sometimes associated with death (Nwaugo *et al.*, 2006). Temperature and pH of water are important parameters in determining the content of total ammonia occurring in un- ionized form; a pH increase of 1 unit brings about a ten-fold increase in the content of un-ionized ammonia (Haruna, 2003). Increase in ammonia content of water is related to poor fish growth, increase in fish vulnerability to diseases and finally the death of the fish (Haruna *et al.*, 1995).

1.1 Feed Utilization Efficiency of *Clarias gariepinus*

Over the years, aquaculture has taken over the use of fish meal as the best source of protein in aquafeed. But fish meal usage has faced serious competition with humans and livestock resulting

in extremely high prices for fish meal. (Ekanem *et al.*, 2010; Eyo and Ekanem 2011, Ekanem *et al.*, 2013). With appropriate feeding rates, fish farmers could reduce the production cost, maximize the culture growth and manage the water quality for a successful farming operation (Marimuthu *et al.*, 2011). *Clarias gariepinus* commands high prices when sold in the market and its production greatly increases (FAO, 2010). *Clarias gariepinus* are usually reared in ponds or different types of tanks at different stocking densities (FAO, 2010). For the extensive culture of this fish, the larvae are fed with cow brain and egg yolk after 4-6 days prior to stocking in fenced nursery ponds. The post-larvae are then fed with single ingredients or compounded feeds. Fingerlings are graded and harvested after 24-48 days and are transferred to the production pond or being sold by the farmers. Different systems are currently being used in growing the catfish including the traditional flooded ponds, pits or ditches, earthen ponds, tanks, raceways and even in cages. Fish nutrition is critical in fish farming because feed represents 40-50% of production cost (Craig and Helfrish, 2002).

Growth performance and nutrient utilization of fish is determined by gross composition of the feed ingredients, processing and storage of the feed products. Globally, there is a great decline in aquaculture production, due to fish feed manufacturers substituting vital feed ingredients with alternative feedstuffs that cannot achieve fish nutritional requirements. One of the critical challenges faced by aquaculture is the high cost of fish feed and more than 50% of the total cost of production is intensified in the culture system (Ali *et al.*, 2004). Fish feed enhances optimum growth and resistance to diseases when it contains the proper proportion of proteins, carbohydrates, lipids, vitamins and minerals. Nevertheless, nutrients in fish feeds are optimally utilized when the feedstuff is acceptable and palatable to the fish. Cost of production can be reduced if growth performance and feed efficiency are increased in commercial aquaculture (Dada and Olugbemi, 2013).

2. Materials and Methods

2.1 Experimental Site

The research was conducted at the Fisheries Shade, Department of Fisheries and Aquaculture, Faculty of Agriculture, Ahmadu Bello University, Zaria.

2.2 Experimental Fish

Two hundred and twenty-five (225) African Catfish (*Clarias gariepinus)* juveniles were procured from Palladan Fish Farm, Samaru, Zaria. The fish were transported in a 50L plastic to the Fisheries Shade in the Department of Fisheries and Aquaculture, Faculty of Agriculture, Ahmadu Bello University, Zaria. The fish were held and acclimatized in a 1000L plastic tank for a period of one week.

2. 3 Design Procedure

The experimental set-up consisted of five plastic bowls with 50cm×33cm×32cm dimension and 70L water holding capacity in Completely Random Design (CRD) in triplicates per treatment of five (5), ten (10), fifteen (15), twenty (20), and twenty-five (25) *C. gariepinus* juveniles. After acclimatization, fish with initial mean weight of 9.76±0.45g and initial length 8.46±0.47cm were randomly stocked in the plastic bowls. The fish were fed 2mm Coppens commercial feed twice daily between 9:00am and 6:00pm at 5% of their body weight for 2 weeks and then gradually transitioned to 3mm Blue Crown commercial feed. The feed for each treatment and its replicate were weighed in separate nylon for onward feeding. 3 fish from each treatment were randomly selected fortnightly, their weights and lengths were measured and the daily ration was adjusted accordingly. Manual change of water was carried out after every 4 days. The plastic bowls were covered with nets to prevent the fish from jumping out and to keep foreign materials from getting inside the bowls.

Plate 1: Image showing *Clarias gariepinus* juveniles stocked at different stocking densities in plastic bowls.

2.4 Determination of Water Quality Parameters

The selected water quality parameters monitored during the study were temperature, pH, dissolved oxygen, and ammonia. Water quality parameters were measured after fortnightly. The water temperature was taken using a HANNA Temperature-TDS meter, while pH, dissolved oxygen, ammonia levels were monitored using a master water test kit.

2.5 Determination of Weight and Standard Length

Fish were weighed using a sensitive digital balance and total length taken in centimeters using centimeter ruler, after being scooped out with a tread. The weight of each fish was taken to the nearest 1.0 g using an Electronic Compact Scale, while the total length was measured to the nearest 0.1cm. The total length, standard length and weight of the fish was recorded fortnightly. Growth rate was calculated percentage increase in length and increase in weight, as expressed in the following equations:

$MWG = Wt_2 – Wt_1$….. (1)

Where MWG = Mean weight gain; Wt_2 = final weight; and Wt_1 = initial weight.

$MLG = Lt_2 – Lt_1$…….. (2)

Where MLG = Mean length gain; Lt_2 = final length; and Lt_1 = initial length.

Determination of Percentage weight gain

PWG (%) =

$$\frac{\text{Final Number of Fish}}{\text{Initial Number of Fish Stocked}} x\ 100 \ldots\ldots. (3)$$

Determination of Specific Growth Rate

SGR (%)

$$=100\ x\ \frac{\text{Ln(Final weight)}\ x\ Ln(Initial\ weight)\ldots}{\text{Duration(days)}}$$

…. (4)

Determination of Feed Conversion ratio $FCR = \frac{\text{Weight of Feed Given}}{\text{Fish Weight Gain}}$ ….….. (5)

Determination of Survival Rate

$$SR\ (\%) = \frac{\text{Final Number of Fish}}{\text{Initial Number of Fish Stocked}}\ x\ 100$$

...…… (6)

Nutrients Composition of Commercial Feed (Blue Crown)

NUTRIENT	**%**
Crude Protein	42.00
Fat	12.00
Ash	8.00
Crude Fiber	4.50
Moisture	10.00
Calcium	1.00 – 1.50
Phosphorus	1.00
Sodium	0.30

2.6 Data analysis

All data collected were subjected to Analysis of Variance (ANOVA) used to determine the level of significance among treatments. Standard deviation was calculated to identify the range of mean. The data from results of analysis were expressed as mean ± SD.

3. Results

3.1 Water Temperature

The mean water temperature in all the treatments ranged between 25.57±0.43 and 27.14±0.36 (℃). The water temperature increased with increasing stocking density and was highest in treatment 25 having

27.14℃. This is considerably lower than the temperature in which *Clarias gariepinus* juveniles will not survive i.e. 40℃. A direct relationship exists between water temperature and dissolved oxygen. The low temperature of about 25℃ reported in this study compared to the about 30℃ reported by Erondu (2015) contributed to the level of dissolved oxygen in this study being higher than 2.2mg/l, the minimum dissolved oxygen level required by *Clarias gariepinus* (Erondu, 2015).

3.2 Dissolved Oxygen

The mean value obtained for the dissolved oxygen in all the treatments ranged between 3.25mg/L and 5.5mg/L, which were within the acceptable limits for fish growth and health (Sahoo *et al.,* 2004). Dissolved oxygen decreased with increasing stocking density and was lowest in the treatment with 25 stocking density (3.25mg/L). The relatively high levels of dissolved oxygen obtained from this study was due to the regular exchange of water. Throughout the period of this study, dissolved oxygen remained comfortably above the minimum 2.2mg/L required for culturing *Clarias gariepinus* (Erondu, 2015). The decrease in the dissolved oxygen levels at higher stocking density is also expected due to increased oxygen consumption by a higher number of fish and higher oxygen demand from her numbers of microbes (Akinwole *et al.,* 2014).

3.3 Ammonia

The Ammonia content in the various treatments ranged between 0.5 and 2.83. Ammonia content increased with increasing stocking density. The highest level of ammonia content was recorded in treatment with stocking density of 25 (2.83±0.28) and was lowest in treatment with stocking density 5 (0.5±16).

3.4 Hydrogen ion concentration (pH)

The mean values of hydrogen ion concentration in all the treatments ranged between 7.06 and 7.15 with the highest pH mean value recorded in the treatment with 25 stocking density. Generally, there was no significant difference between the concentration of hydrogen ions across the various treatments (p=0.5). Throughout the period of the study, pH remained within the acceptable limits of 6.5 – 9.0 (Nwipie, 2014).

3.5 Mean Weight Gain (g)

The mean initial weight in the five treatments was 9.77±0 (g); the range was between 9.27g and 10.24g while the mean final weight in all the treatments was 50.31±87.23, ranging between 20.15g to 114.48g. Analysis on the weight gain showed that weight gain decreased as the stocking density increased. The treatment with stocking density 5 had the highest mean final weight of 59.24±3.09 (g). Treatments with stocking densities 20 and 25 had the lowest final mean weight gain of 43.17±2.55 (g) and 48.23±4.13 (g) respectively. The result of the analysis on the final mean weights showed that there was significant difference (P<0.05) between the weight gain in all the

Table 1: Water quality parameters monitored across all treatments of African Catfish (*C. gariepinus*) raised at five different stocking densities in 70L plastic bowls.

Parameter	5	10	15	20	25
D.O	**5.33±0.24**	**5.5±0.03**	**4.43±0.14**	**3.65±0.55**	**3.25±0.46**
Temp.	**25.57±0.43**	**25.83±0.68**	**26.19±0.75**	**27.06±0.43**	**27.14±0.36**
pH	**7.06±0.03**	**7.15±0.1**	**7.1±0.05**	**7.1±0.05**	**7.15±0.08**
NH_3	**0.5±0.16**	**0.94±0.32**	**1.29±0.52**	**1.16±0.19**	**2.83±0.28**

D.O: *dissolved oxygen (mg/L),* ***Temp.:*** *temperature (℃),* ***pH:*** *hydrogen ion concentration,* ***NH_3:***

The mean initial length was 8.46±0 (cm), ranging between 7.9cm to 9.2cm. The final mean length in all the treatment was
treatments.

3.6 Specific Growth Rate

The specific growth rate in this study shows that as the stocking density increases, the growth rate decreases. Treatment with stocking density 5 had the highest specific growth rate (4.04).

3.7 Feed Conversion Ratio

The analysis of the feed conversion ratio, which expresses the efficiency of fish in converting feed to flesh, was highest in the treatment with stocking density of 5 (0.41). The feed conversion showed an inverse relationship with the stocking density: as stocking density increased, the feed conversion ratio decreased. There was no significant difference (P<0.05) in the FCR in all the treatments.

3.8 Survival Rate

The survival rate across the treatments ranged between 80-100%. Survival rate decreased with increasing stocking density. The highest survival rate (100%) was recorded in the stocking density 5.

4. Discussion

Knowing the appropriate stocking density to use is critical for boosting fish production to meet rising demand while also ensuring the profitability and economic sustainability of an aquaculture operation (Basuki *et al.*, 2007). According to Taufek *et al.,* (2016), fish growth, survival, and behavior are all known to be influenced by stocking density

Table 2: Growth performance, nutrient utilization and survival rates across all treatments of African Catfish (*C. gariepinus*) raised at five different stocking densities in 70L plastic bowls.

SD	ILT	FLT	IWT	FWT	PWG	SGR	FCR	SR
5	8.43±0.40	18.84±0.56	10.24±0	59.24±3.09	963.32±117.56	4.04±0.18	0.41±0.06	100
10	8.46±0.42	18.45±0.86	9.63±0	51.03±9.38	899.82±253.14	3.88±0.47	0.87±0.26	93.33
15	8.8±0.69	18.47±0.31	10.3±0	49.88±0.57	831.09±56.79	3.77±0.13	2.24±0.53	91.11
20	8.57±0.51	18.13±0.19	9.35±0	43.17±2.55	792.51±111.49	3.67±0.27	2.23±0.27	80
25	8.03±0.15	18.37±0.19	9.27±0	48.23±4.12	920.1±73.90	3.86±0.26	1.88±0.01	81.33

***SD:** stocking density, **ILT**: initial length(cm), **FLT**: final length(cm), **IWT**: initial weight(g), **FWT**: final weight(g), **PWG**: percentage weight gain (%), **SGR**: specific growth rate, **FCR**: feed conversion ratio, **SR**; survival rate (%).*

The results showed that stocking density has significant impact on the growth performance, water quality, nutrient utilization and survival of African Catfish (*Clarias gariepinus*). Water quality in the plastic bowls deteriorated with increasing stocking density. Water temperature in this study was within the ideal temperature (2033°C) required for the culture of African Catfish (*Clarias gariepinus*), as reported by Adeogun *et al.,* (2004). The pH levels ranged between 7.06 and 7.15 which was similar to a work done by Nwipe (2014) which reported that the acceptable pH range for the culture of African catfish (*Clarias gariepinus*) was 6.5– 9.0. Low amounts of ammonia content were measured in treatments with stocking density 5–20. However, the highest level of ammonia (2.85) in this study was recorded in the treatment with stocking density 25. According to Diana and Fast (1989), high stocking density leads to an increase in fish activity (air breathing, swimming), which results in higher ammonia concentration and thereby, negatively affecting water quality. The result showed that there is an inverse relationship between stocking density and dissolved oxygen. Although there was no significant difference in the dissolved oxygen levels that was recorded during this study, which can be attributed to regular exchange of water, treatment

with the highest stocking densities (25) had the lowest levels of dissolved oxygen. This agrees with a similar report by (Akinwole *et al.,* 2014) that says oxygen consumption increases as a result of high number of fish.

Bjoernsson (1994) reported that under crowded conditions, fish suffer stress as a result of aggressive feeding interaction and eat less, resulting in growth retardation. In this study, treatments with higher stocking density had the lowest growth performance. The specific growth rate decreased with increasing stocking density. Treatment 5 had the highest specific growth rate. Feed conversion ratio in this study decreased with increasing stocking density. The reduction in FCR with increasing density can be attributed to the feeding behavior of catfish (AlmazánRueda, 2004). Survivability of African Catfish (*Clarias gariepinus*) decreased with increasing stocking density. While there was no significant difference in the survival rates across the treatments, it was better (100%) at the treatment with the lowest stocking density (5). The high survival rate recorded across all treatments could be partially attributed to the proper monitoring and management of the physiochemical parameters of water and also to the good health condition of the fish. The survival rate ranged between 80–100%.

5. Conclusion

From the results obtained from this study, growth performance was generally good in all treatments. However, stocking density of 5–15 juvenile African catfish (*Clarias gariepinus*) per 70L plastic bowl had the best performance. This study has established that the growth performance and survival of cultured African Catfish is dependent on the stocking density. Therefore, commercial culture of African catfish in plastic bowls should be done within the proper stocking density. This study further demonstrates that it will probably be unprofitable to stock juvenile African catfish at high stocking densities, especially in 70L plastic bowls. Amongst the several harmful impacts that high stocking density had on the culture includes decrease in growth, weight gain, survival rates and food conversion ratio, which are all necessary for successful fish production.

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Article 4

Coding for Beginners: A Case of Boot Camp of 40 Learners in Lusaka District, Zambia

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Abstract

In the digital age, coding has become a highly sought-after skill, driving innovation and economic growth. However, many individuals and organizations in developing countries like Zambia lack the necessary skills to participate in this digital economy. This study investigated the effectiveness of a coding boot camp program for beginners in Lusaka district, Zambia. A mixed-methods approach was employed, combining quantitative and qualitative data collection methods. Forty learners participated in a 12-week coding boot camp program, and their learning outcomes were assessed through pre- and post-tests. Semi-structured interviews were also conducted to gather learners' perceptions of the program. The study found that the coding boot camp program was effective in equipping beginners with basic programming skills, with significant improvements observed in their coding abilities after completing the program. The study highlighted the importance of accessible and affordable coding training programs in bridging the digital divide. The findings suggest that coding boot camps can be an effective way to equip beginners with coding skills, but more research is needed to understand the long-term impact of such programs on individuals and communities. This study recommends that policymakers and organizations invest in accessible and affordable coding training programs to bridge the digital divide. The findings have implications for education and training programs in developing countries, highlighting the need for innovative approaches to address the growing demand for coding skills in the digital age.

Key Words*: Coding, Boot Camp, Digital Age, Innovations, Economic Growth*

1. Introduction

The global economy is undergoing a profound transformation, increasingly shaped by digital technologies. The ability to understand, manipulate, and create with technology is no longer a niche skill but a fundamental literacy for the 21st century (World Bank, 2019). At the heart of this digital revolution lies coding—the process of designing and building executable computer

programs to accomplish a specific computing result. Coding skills are the engine of innovation, driving advancements in fields from agriculture and healthcare to finance and entertainment.

For developing nations like Zambia, this digital shift presents both a significant challenge and a unprecedented opportunity. The challenge is the persistent digital divide—the gap between those who have access to modern information and communication technology (ICT) and the skills to use it, and those who do not (Van Dijk, 2020). This divide threatens to exacerbate existing inequalities, leaving many Zambians behind in an increasingly connected world. The opportunity, however, lies in the potential for digital skills to catalyse economic diversification, create new employment pathways for the youth, and foster local innovation to solve local problems (ICTAZ, 2022).

The Zambian government, through its Eighth National Development Plan (8NDP) and the Smart Zambia Initiative, has recognized the critical importance of ICTs for national development. A key pillar of this strategy is human capital development, specifically building a digitally skilled workforce (Government of the Republic of Zambia, 2022). However, the formal education system, often constrained by curriculum rigidity, limited resources, and insufficiently trained teachers, struggles to keep pace with the rapidly evolving demands of the tech industry (Banda & Mweemba, 2021).

In this context, alternative, agile, and intensive training models have emerged globally to fill this skills gap. Coding boot camps are short-term, immersive training programs designed to equip participants with practical, job-ready programming skills in a matter of months (Kaplan-Leiserson, 2020). While popular in North America and Europe, their efficacy and applicability in a resource-constrained environment like Zambia remain under-researched.

This study, therefore, seeks to address this gap by evaluating a pilot coding boot camp implemented in Lusaka. It aims to answer the following research questions:

- To what extent does a 12-week coding boot camp improve the basic programming skills of complete beginners in Lusaka?
- What are the learners' perceptions and experiences regarding the boot camp's content, delivery, and overall impact on their digital literacy and career aspirations?

2. Literature Review

2.1 The Global Imperative for Digital Skills

The demand for digital skills is a global phenomenon. The European Commission estimates that by 2030, over 90% of jobs will require some level of digital proficiency (European Commission, 2021). In Africa, the African Development Bank (2020) highlights that investing in STEM and digital skills is non-negotiable for harnessing the continent's demographic dividend and accelerating industrialization. Coding, as a foundational digital skill, empowers individuals not just to use technology but to create it, positioning them as active contributors to the digital economy.

2.2 The Digital Divide in the Zambian Context

Despite progress, Zambia's digital divide remains stark. Internet penetration stands at approximately 40% (ZICTA, 2023), with access concentrated in urban areas like Lusaka. Beyond infrastructure, there is a significant skills gap. The education system produces few ICT graduates, and even fewer with the practical, project-based experience demanded by employers. This creates a cycle where a lack of skilled workers stifles the growth of the local tech industry, which in turn fails to create demand for more talent.

2.3 Coding Boot Camps as an Alternative Model

Coding boot camps originated in the early 2010s as a market-driven response to the tech talent shortage. Their model is characterized by:

- Immersive Intensity: Full-time, focused learning over a short period.
- Project-Based Curriculum: Learning by doing, culminating in portfolio projects.
- Industry-Relevant Skills: Teaching languages and frameworks currently in demand.
- Cohort-Based Learning: Fostering a collaborative community.

Research in Western contexts has shown boot camps to be effective in increasing employment rates and salaries for graduates (Stevenson, 2019). However, their replication in Africa requires adaptation, considering challenges like internet reliability, cost, and varying educational backgrounds.

2.4 Gap in Knowledge

While the potential of boot camps is acknowledged, there is a scarcity of empirical, peer-reviewed studies evaluating their effectiveness in specific Sub-Saharan African contexts like Zambia. Most reports are from boot camp providers themselves or international NGOs. This study aims to contribute rigorous, localized evidence to this emerging field.

3. Methodology

3.1 Research Design

This study employed a mixed-methods approach to provide a comprehensive evaluation of the boot camp's effectiveness. A convergent parallel design was used, where quantitative and qualitative data were collected concurrently during the intervention, analysed separately, and then merged to interpret the overall results (Creswell & Plano Clark, 2017).

3.2 Participants and Sampling

A purposive sampling technique was used to select 40 participants from a pool of over 200 applicants in Lusaka District. Inclusion criteria were: being aged 18-35, having completed

secondary education, demonstrating strong motivation to learn coding, and having no prior formal programming experience. The cohort consisted of 22 males and 18 females.

3.3 The Intervention: The 12-Week Boot Camp

The boot camp was conducted over 12 weeks, with sessions held on weekends to accommodate learners who were working or in school. The curriculum was structured as follows:

- Weeks 1-2: Digital Literacy & Computational Thinking (Introduction to computers, problem-solving algorithms).
- Weeks 3-5: Front-End Foundations (HTML5, CSS3).
- Weeks 6-9: Introduction to Programming (JavaScript fundamentals: variables, functions, loops, DOM manipulation).
- Weeks 10-12: Capstone Project (Designing and building a personal portfolio website).

Instruction was facilitated by two experienced tutors and utilized a blend of short lectures, live coding demonstrations, pair programming, and individual project work. Learning resources were provided via a shared offline server to mitigate internet costs and connectivity issues.

3.4 Data Collection

Quantitative Data: A 50-question multiple-choice test assessing basic knowledge of HTML, CSS, and JavaScript concepts was administered as a pre-test on the first day and as a post-test on the final day. The test was validated by two independent ICT lecturers.

Qualitative Data: Semi-structured interviews were conducted with 15 randomly selected participants after the post-test. Interview questions explored their learning journey, challenges faced, perceived skill acquisition, and changed attitudes towards technology and their future careers. Each interview lasted approximately 20-30 minutes and was audio-recorded.

3.5 Data Analysis

Quantitative Analysis: Pre-test and post-test scores were compiled and analysed using SPSS software (Version 28). A paired-samples t-test was conducted to determine if there was a statistically significant difference between the mean scores before and after the intervention.

Qualitative Analysis: Audio recordings were transcribed verbatim. Thematic analysis, as outlined by Braun and Clarke (2006), was employed. This involved familiarization with the data, generating initial codes, searching for themes, reviewing themes, and defining and naming them.

3.6 Ethical Considerations

Informed consent was obtained from all participants. They were assured of anonymity and confidentiality. Participation was voluntary, and learners could withdraw at any time without penalty.

4. Results and Findings

4.1 Quantitative Results: Skill Acquisition

The pre-test mean score was 22.4% (SD = 8.1), indicating very limited prior knowledge, as expected. The post-test mean score rose dramatically to 78.5% (SD = 10.3). A paired-samples t-test confirmed that this improvement was statistically significant, $t(39) = 25.67$, $p < .001$. The large effect size (Cohen's $d = 3.2$) indicates a substantial and meaningful increase in coding knowledge.

Table 1: Pre-test and Post-test Score Comparison

Assessment	N	Mean Score (%)	Standard Deviation	t-value	p-value
Pre-test	40	22.4	8.1	25.67	< .001
Post-test	40	78.5	10.3		

4.2 Qualitative Findings: Learner Perceptions and Experiences

i. Thematic analysis of the interview data revealed four main themes:
Transformation from Consumers to Creators of Technology: Many participants expressed a profound shift in identity. "I used to just browse Facebook and WhatsApp," one participant noted, "but now I understand how these things are built. I can even build a simple page myself." This shift from passive consumption to active creation was a powerful and motivating outcome.

ii. Increased Confidence and Self-Efficacy: Despite initial intimidation, learners reported a major boost in confidence. "The first time I wrote a function and it actually worked, I felt like a genius," said another. Overcoming the challenge of learning a completely new and complex skill set fostered a strong sense of self-efficacy that many believed would transfer to other areas of their lives.

iii. The Double-Edged Sword of Intensity: The immersive, fast-paced nature of the boot camp was consistently highlighted. It was praised for enabling rapid learning but was also identified as the primary source of stress and challenge. "You have to be dedicated. If you miss one day, you are left behind," a participant cautioned.

iv. Navigating Infrastructural Hurdles: The unreliable internet connectivity and the high cost of data were the most frequently cited external challenges. Participants appreciated the use of offline resources but noted that the inability to easily search for solutions online during power outages sometimes hindered their progress.

5. Discussion

This study demonstrates that a well-structured coding boot camp can be a highly effective intervention for imparting foundational programming skills to beginners in Zambia. The

statistically significant improvement in test scores provides strong quantitative evidence for the model's efficacy in a resource-constrained environment.

The findings align with global literature on the success of boot camps (Stevenson, 2019) but crucially contextualize it within the Zambian reality. The qualitative data enriches the quantitative results by revealing the transformative experience of learning to code—the growth in confidence, the shift in mind-set, and the awakening of career aspirations. This suggests that the boot camp's impact extends beyond mere skill acquisition to fostering a digital mind-set crucial for long-term adaptability.

The challenges identified, particularly around infrastructure (internet, electricity), are consistent with known barriers to digital adoption in Sub-Saharan Africa (GSMA, 2023). This study suggests that these challenges are not insurmountable. Mitigation strategies, such as using offline coding environments and providing dedicated learning spaces with generators, can be effectively implemented.

The success of this pilot supports the Zambian government's focus on alternative skilling pathways as complementary to the formal education system. Boot camps offer agility, allowing curricula to be quickly updated to reflect industry trends, a flexibility that traditional universities often lack.

6. Conclusion and Recommendations

6.1 Conclusion

This research provides compelling evidence that coding boot camps are a viable and effective model for rapidly developing digital skills among beginners in Lusaka, Zambia. The program successfully transformed a cohort of novices into individuals with functional programming knowledge and a newfound confidence in their ability to engage with technology. While infrastructural challenges exist, they can be managed with proactive planning. This model represents a powerful tool for bridging the digital divide and equipping Zambian youth with the skills needed to participate in the global digital economy.

6.2 Recommendations

Based on the findings, the following recommendations are proposed:

For Policymakers (Ministry of Education, Ministry of Technology and Science):

i. Integrate boot camp models into national youth empowerment and skills development programs.
ii. Develop policy frameworks and funding mechanisms to support the scaling of proven coding initiatives, particularly those targeting women and rural populations.
iii. Foster public-private partnerships to ensure boot camp curricula remain industry-relevant.

For Educational Institutions (Universities, Colleges, National Science Centre):

i. Incorporate short, intensive boot camps as supplementary or pre-university programs to spark interest in ICT fields.
ii. Adopt the project-based and immersive pedagogical approaches of boot camps into formal ICT curricula.

6.3 Limitations and Suggestions for Future Research

This study was limited to a small sample in an urban setting over a short period.

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Article 5

The Influence of SMASE Practical Approach Toward's Enhancing the Teaching of STEM Subjects in Kudan local Government Area of Kaduna State Nigeria

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Abstract

This study examines the impact of the Strengthening Mathematics and Science Education (SMASE) practical approach, specifically the Activity, Student-Centered, Experiment, and Improvisation - Plan, Do, See, and Improve (ASEI-PDSI) model, on enhancing STEM (Science, Technology, Engineering, and Mathematics) education in Kudan Local Government Area, Kaduna State. The research aims to foster positive changes in teachers' attitudes toward their profession, particularly in the teaching of mathematics and science, by improving subject mastery, pedagogical skills, resource utilization, and student engagement in classroom activities. Additionally, it seeks to strengthen teachers' ability to deliver student-centered lessons through well-planned ASEI lessons.

The SMASE initiative, designed to elevate the quality of STEM education, trained 34 teachers from various disciplines, including mathematics, engineering, science, robotics, and agriculture, using the ASEI-PDSI approach. Two versions of a 25-item questionnaire, covering categories A to E, were administered to the teachers before and after the training sessions. The pre-INSET questionnaire was given before the sessions commenced, and the post-INSET questionnaire was administered at the conclusion. Participants responded to each item on a 5-point scale, with scores interpreted as follows: a mean score (m) below 3.0 indicated a negative attitude, $4.0 \leq m < 4.5$ suggested a shift toward a positive attitude, $m \geq 4.5$ reflected a positive attitude, and $3.0 \leq m \leq 3.9$ denoted neutrality.

The results demonstrated that teachers reported increased confidence and effectiveness in delivering STEM content. The study concludes that the SMASE practical approach (ASEI-PDSI) is a viable and effective strategy for enhancing STEM education. It recommends broader adoption and ongoing professional development to sustain and expand these positive outcomes.

Keywords: influence, SMASE practical approach, stem subjects, enhancement, kudan, educational outcome, Nigeria

Sub-theme: "Innovative STEM Education Through SMASE: Transforming Teaching Practices in Kudan LGA, Kaduna State"

1. Introduction

The National Teachers' Institute (NTI), Kaduna, was established with a clear mandate to improve the quality of teaching and learning across Nigeria. By focusing on the training and retraining of teachers at all educational levels, NTI has become a cornerstone of the nation's efforts to shape its educational landscape. One of its key initiatives is the Strengthening Mathematics and Science Education (SMASE) Nigeria Programme, a collaborative effort between the Federal Ministry of Education and the Japan International Cooperation Agency (JICA). The SMASE programme is designed to provide in-service training for mathematics and science teachers, equipping them with the tools and techniques needed to improve STEM education.

STEM (Science, Technology, Engineering, and Mathematics) subjects are critical for fostering innovation, technological advancement, and national development. However, there has been growing concern about the quality of STEM education in Nigeria, particularly in regions like Kaduna State. To address these concerns, the SMASE initiative promotes a practical teaching approach known as ASEI-PDSI (Activity, Student, Experiment, Improvisation - Plan, Do, See, Improve). This approach aims to enhance the quality of teaching by developing teachers' pedagogical skills, improving subject mastery, and encouraging an interactive, student-centered classroom environment.

In Kudan Local Government Area of Kaduna State, the impact of the SMASE practical approach is notable in improving the delivery of STEM education. By shifting from traditional, lecture-based methods to more engaging, student-centered strategies, the ASEI-PDSI model encourages active student participation and hands-on experimentation with scientific concepts. This study explores how the SMASE approach influences teacher attitudes, pedagogical practices, and student engagement, offering valuable insights into its effectiveness in enhancing STEM education within the region.

2. Literature Review

The quality of STEM (Science, Technology, Engineering, and Mathematics) education is essential for a nation's growth and development, particularly in the context of developing countries like Nigeria. Globally, efforts have been made to improve the teaching and learning of STEM subjects, with research emphasizing the importance of active learning, teacher professional development, and practical, student-centered approaches (Boaler, 2016). In this context, the Strengthening Mathematics and Science Education (SMASE) initiative, which promotes the ASEI-PDSI (Activity, Student, Experiment, Improvisation - Plan, Do, See, Improve) teaching model, has been

implemented in several African countries, including Nigeria, to address challenges in STEM education.

Teacher training and professional development are widely regarded as critical factors in enhancing STEM education. According to Darling-Hammond et al. (2017), teachers who receive continuous professional development are more likely to adopt innovative teaching methods, improve their subject mastery, and positively impact student learning outcomes. The SMASE initiative aligns with this view by offering in-service training for mathematics and science teachers, focusing on enhancing their pedagogical skills and encouraging active participation in the learning process. Research by Otieno (2018) in Kenya demonstrated that teachers trained under the SMASE model exhibited greater confidence in their teaching abilities and were better able to engage students in STEM-related activities.

The ASEI-PDSI framework, a central feature of the SMASE initiative, emphasizes shifting from traditional teacher-centered approaches to student-centered, hands-on learning. The model encourages teachers to plan and implement lessons that actively involve students in activities, experiments, and improvisation, leading to better comprehension of scientific concepts (Yara & Otieno, 2010). Studies by Mureithi (2015) found that this approach significantly improved student engagement and achievement in STEM subjects, as it allowed students to explore concepts through practical experiences rather than passive learning.

Despite its effectiveness, several challenges hinder the successful implementation of the SMASE approach in different contexts. Research conducted by Yusuf (2019) in Nigeria highlighted issues such as inadequate infrastructure, limited access to teaching materials, and insufficient funding as major barriers to the full adoption of the ASEI-PDSI model. Additionally, teachers often face resistance to changing from traditional teaching methods to more interactive, student-centered approaches due to a lack of adequate training and support. In regions like Kaduna State, overcoming these challenges requires concerted efforts from stakeholders in the education sector, including government and international organizations.

In Nigeria, where the quality of STEM education has been a growing concern, the SMASE practical approach has shown potential in improving both teaching practices and student learning outcomes. According to Usman et al. (2020), teachers who participated in the SMASE training demonstrated improved pedagogical skills, better classroom management, and a more positive attitude toward teaching STEM subjects. The study also noted that students in SMASE-implemented schools were more engaged and performed better in STEM subjects compared to their peers in non-SMASE schools. However, further research is needed to assess the long-term impact of the ASEI-PDSI model in rural areas like Kudan Local Government Area, Kaduna State.

The existing literature supports the effectiveness of the SMASE practical approach in enhancing the teaching and learning of STEM subjects by improving teacher competence and promoting student-centered learning. However, challenges such as resource constraints and resistance to pedagogical change remain significant obstacles. In the context of Kudan Local Government Area, further studies are required to fully understand the influence of the SMASE approach on teaching practices and student outcomes.

2.1 Participants

The total of 34 teachers participated in the training with the gender distribution as follows: 25 males and 9 females.

Males	Females	Total
25	9	34

Table 1: Gender Distributions of Participants

The training was facilitated by SMASE National Trainers from the National Teachers' Institute.

2.2 Training Objectives

The objectives of the training were to:

1. Foster a positive change of teachers' attitude to the teaching profession in general and the teaching and learning of mathematics and science in particular;
2. Improve performance of teachers in subject mastery, pedagogical skills and resource utilization as well as pupils' participation in classroom activities;
3. Enhance the teaching skills of teachers in mathematics and science;
4. Enhance ability of basic school teacher to conduct student-centered lessons in mathematics and science and Plan better ASEI Lessons.

2.3 Content of Training

The training content comprised of the following:

2.3.1 Chapter One

i Importance of teaching STEM Education
ii Child psychology in teaching and learning STEM Subjects
iii Gender Sensitivity in teaching and learning STEM Subjects
iv Creating CCAT learners: Critical, Creative and Analytical Thinkers
v Principles of Student-Centred Approach
vi Planning Activity-Based Lessons in STEM

vii Improvisation of instructional materials in teaching and learning
viii Practical Activities in the Laboratory
ix Integrating ICT in STEM teaching

2.3.2 Chapter Two

i Effective teaching and learning of Human Skeletal System
ii Effective teaching and learning of Robotics
iii Effective teaching and learning of 3-Dimensional Shapes
iv Effective teaching and learning of Soil Erosion

3. Achievements and Results of the Training

3. 1 What Participants Gained from the INSET

Participants unanimously expressed that the INSET programme proved to be highly valuable, offering them significant gains across various aspects of their professional development. The following are the top seven common areas where participants reported tangible benefits:

S/N	Comments
1.	Cultivation of a positive and proactive attitude among participating teachers.
2.	Comprehensive training on diverse methodologies for implementing STEM lessons.
3.	Integration of real-world examples and practical applications into the training curriculum.
4.	Emphasis on fostering interactive and engaging learning environments.
5.	Opportunities for collaborative learning and sharing of best practices among teachers.
6.	Tailoring of the training programme to creating CCAT Learners (Creative, Critical and Analytical Thinkers).
7.	Transformation in Attitudes towards Teaching and Learning of STEM Subjects.
8.	Acquisition of Versatile Strategies for Implementing STEM Lessons using Activity-Based, Student-Centred Approach.
9.	Enhanced Time Management Skills
10.	Mastery in Provision and Utilization of improvised resources/Teaching Learning

	Materials (TLMs) to support effective lesson planning and execution.
11.	Clarification of Complex Concepts and Difficult Topics in STEM Subjects.
12.	Development of Collaborative and Interactive Teaching Approaches
13.	Improvement in Classroom Management Techniques and Discipline Strategies

Table 3: Key Gains (What Participants Gained) from the INSET Programme

3.2 Pre and Post Evaluation Questionnaires

3.2.1 Objective

The objective of administering the Pre and Post INSET evaluation was to gauge the participants' conception of the various issues involved in the teaching and learning of STEM subjects in their classes before and after exposure to SMASE INSET respectively.

This was to assess the extent of positive change in attitudes towards teaching and learning of STEM subjects while planning Activity-Based Lessons attributable to the SMASE training for the Kudan LGA Teachers.

3.2.2 Method

Two versions of questionnaires of 25 questions comprised of categories A to E were administered to 34 teachers of Kudan LGA of Kaduna State. The Pre-INSET questionnaire was administered just before sessions began while post-INSET questionnaire was administered at the end of the INSET sessions. In each case the participants responded to items in the questionnaire by choosing one of the 5 options given in each item.

A mean score (m) of $m<3.0$ indicates a negative attitude towards the issues raised by the items whereas a score of $4.0\leq m<4.5$ reflects an attitude that is on the path to attaining the desired positive status. A score of $m\geq 4.5$ indicates that a positive attitude has been attained while $3.0\leq m\leq 3.9$ points to a neutral attitude.

3.3.3 Population

Both Pre and Post Evaluation Questionnaires were distributed to the Participants at the beginning and at the end of the training. The number of Respondents is shown in Table 6:

Pre-INSET Evaluation	**34**
Post-INSET Evaluation	**34**

Table 6: Number of Respondents

3.3.4 Graphical Presentation

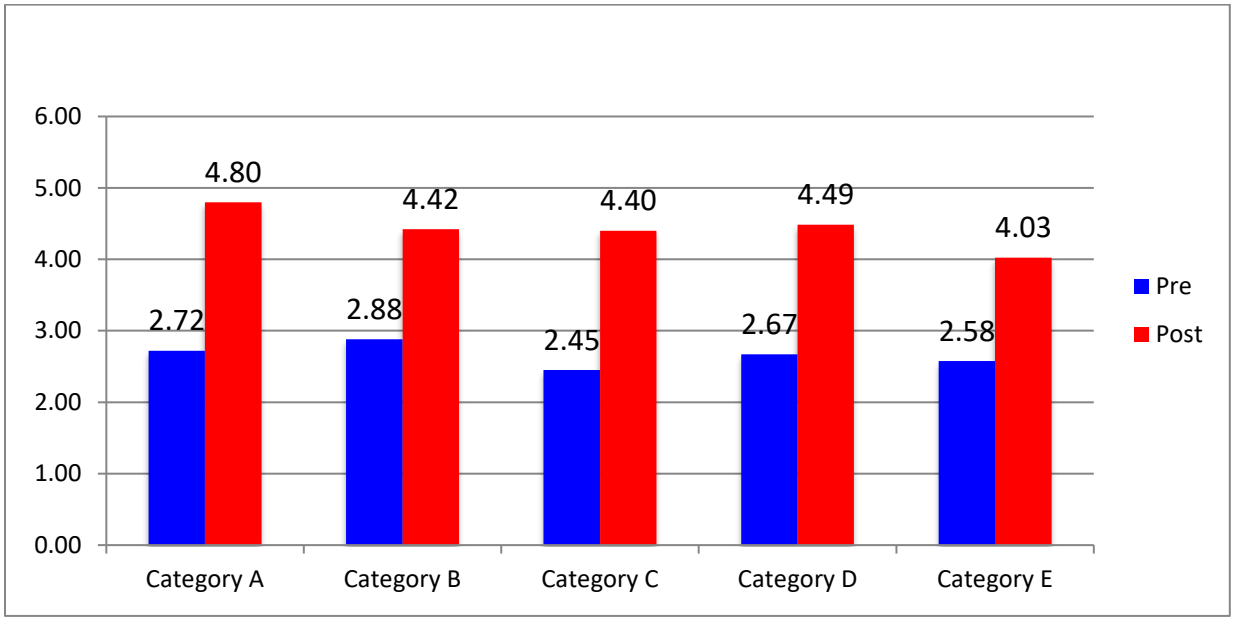


Figure 2.1 Pre-Post INSET Evaluation Graph

3.3.5 Observation

Following the analysis of pre-post evaluations, it was evident that there has been a significant positive change in the knowledge and skills acquisition of participating teachers. Category A questions (Attitudes towards the purpose of teaching/learning) reveals a mean score of 4.80 and 2.72. Category B questions (Attitude towards methodology) reveal a mean score of 4.42 and 2.88, Category C (Attitude towards lesson planning) reveals a mean score of 4.40 and 2,45 while Categories D (Attitude towards overcoming limitation) and E (Attitude towards teaching and learning activities) reveals 4.49 / 2,67 and 4.03 / 2.58 respectively. The post-training evaluation reflecting a mean score of above 4.00, indicates enhanced abilities in several key areas, including Activity-Based lesson planning, effective time management, and fostering improved classroom interaction.

3.3 Session Evaluation Questionnaire

3.3.1 Objective

Quality assurance of SMASE INSET is an important factor to continue the training and ensure the quality of the subsequent trainings in cascading down during the School-Based Training (SBT). The activities have to capture attention of participants as relevant and beneficial to their professional needs, and allow participants to fully understand the rationale behind the activities so that they could teach other teachers in the cascade down during the School-Based Training (SBT). In order to enable National Trainers, identify areas to be improved upon in the session, the questionnaire "Session Evaluation Questionnaire" were administered to allow participants to give feedback on each session.

3.3.2 Method

This instrument was developed as an evaluation form which participants filled soon after a given session is over. Participants rated the session in terms of the following five criteria, overall, relevance of topic, facilitation, clear instruction on activities and time management. These five criteria are considered as "**quality criteria".**

These were scored by given numerical rate whose scale was from 1 to 5 (1=Poor, 2=Fair, 3=Good, 4=Very Good, 5=Excellent). The collected rating was used for quantitative analysis on each session.

3.3.3 Population

The instrument was distributed to all participants in the INSET. The number of respondents per session is shown below.

Analysis on Individual Sessions based on Session Evaluation Questionnaire

Session 1: Importance of Teaching STEM Subjects

The importance of Science, Technology, Engineering, Mathematics (STEM) and other STEM subjects such as Agriculture cannot be overemphasized. In order to prepare learners to function effectively in our society and in the modern world learners need to be exposed to the products and importance of Science, Technology, Engineering and Mathematics. The objective of the session was to identify the content and importance of teaching STEM subjects (Science, Technology, Engineering, Mathematics, Agriculture) in relation to learners' daily lives.

At the end of the session, session evaluation was administered and the result is as shown below:

Result of Question 1:

Figure 1: Quality Criteria for of teaching STEM subjects

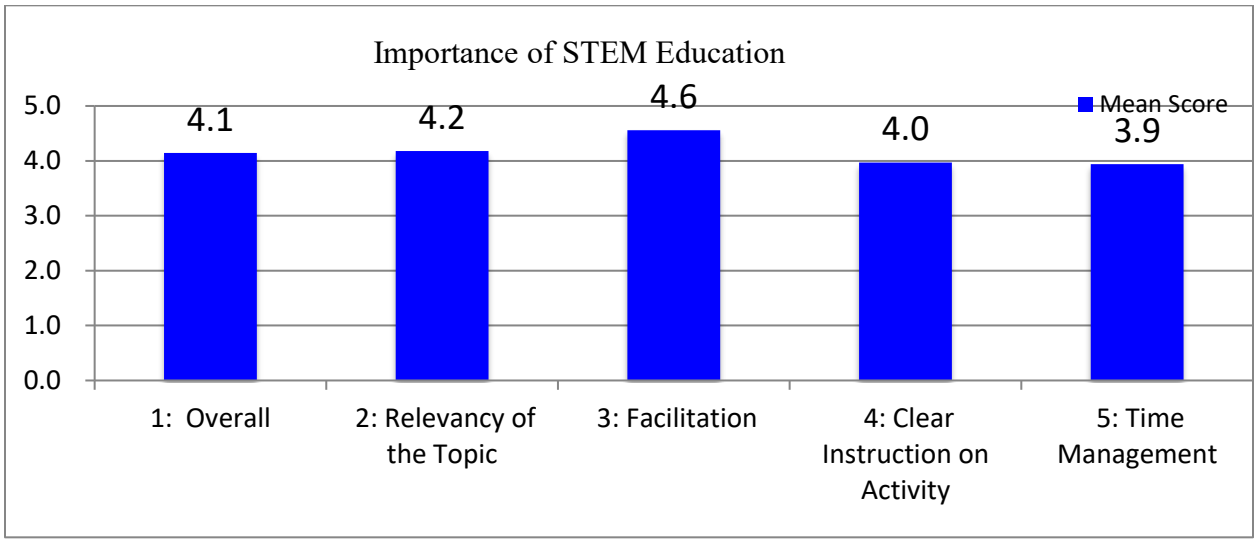


Figure 1: Quality Criteria Importance of STEM Education.

The overall rating of the session was 4.1 which showed that the targeted mean score was attained, hence the objective of the session was achieved. Facilitation was rated 4.6 showing the facilitator enhanced learning during the session.

Result of Question 2: Which of this session can be applied in your work?

1	Agriculture – I like farming.
2	All parts of the session. I now have a better understanding of Science and Technology.
3	Group work – I always appreciate group work because it makes me understand things easier and better.
4	Technology – this is because we are in a technological era where computers can be used to perform so many tasks within a short time frame.

The participants demonstrated a good appreciation of the importance of STEM Education. Their interest during the session was more on Agriculture/farming.

Result of Question 3: Which part of this session is found to be difficult to understand? Give the reasons.

1	No part.

2	None.
3	The statistics part.

From the sampled responses, most of the participants had a good understanding of the session except for one who had difficulty in understanding the importance of statistics but to a large extent, he was guided on understanding the everyday use of statistics across all disciplines and the misconceptions about the topic was cleared.

Result of Question 4: Any comments?

1	I enjoyed and appreciate the facilitator for a well delivered session.
2	None.
3	The session is impactful in appreciating the everyday use of Science, Technology, Engineering, Mathematics and Agriculture.

From the comments above, it was observed that the participants appreciated the session.

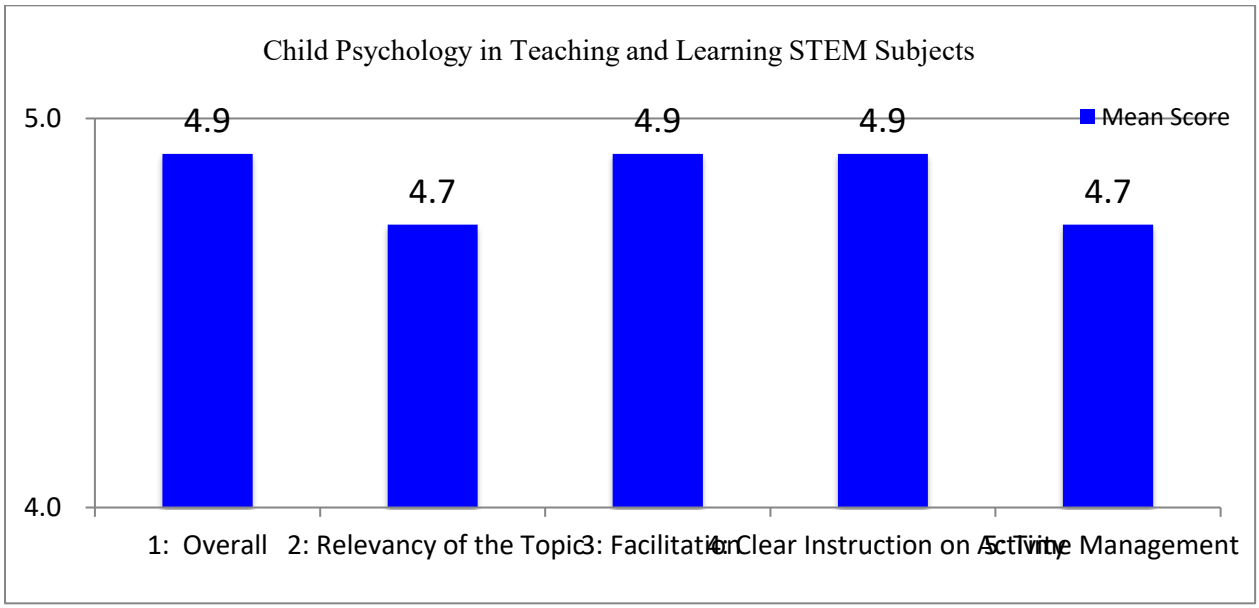
Session 2: Child Psychology in Teaching and Learning STEM Subjects

Teaching and learning are intricately connected to the learner's psychology. For teachers to meet their learning goals, they need not only understand their learners' psychology, but to tailor their content in a way that resonates with learners' behavior. By infusing child psychology principles into teaching approaches, teachers craft inclusive learning environments tailored to each student's learning needs and hence fostering academic, social, and emotional growth.

At the end of the session, session evaluation was administered; the result is as shown below:

Result of Question 1:

Figure 2: Quality Criteria for Child Psychology in teaching and learning STEM subjects



The overall rating of the session was 4.9 which showed that the targeted mean score was attained; hence the objective of the session can be said achieved. Facilitation was rated 4.9 which was an encouraging one from the side of the facilitator. There was also a great improvement on time management has been observed.

Result of Question 2: Which of this session can be applied in your work?

1	All parts.
2	All parts because they are all relevant.
3	All parts are applicable to my work.
4	Integrate child psychology in teaching and learning
5	Understand the developmental stages and apply them into teaching and learning.

Result of Question 3: Which of this session is found to be difficult to understand?

1	None.
2	No one.
3	Nil.

4	No, I have understood it all.
5	None, all the parts are treated well with the understanding of the facilitator.

Some participates are of the view that proper understanding of child's behavior at each stage of the developmental stage is sometimes difficult.

Result of Question 4: Any comments?

1	There should be more and more INSETs.
2	I appreciate you all.
3	Good presentation.

From the comments above, it was observed that the participants really happy with the session.

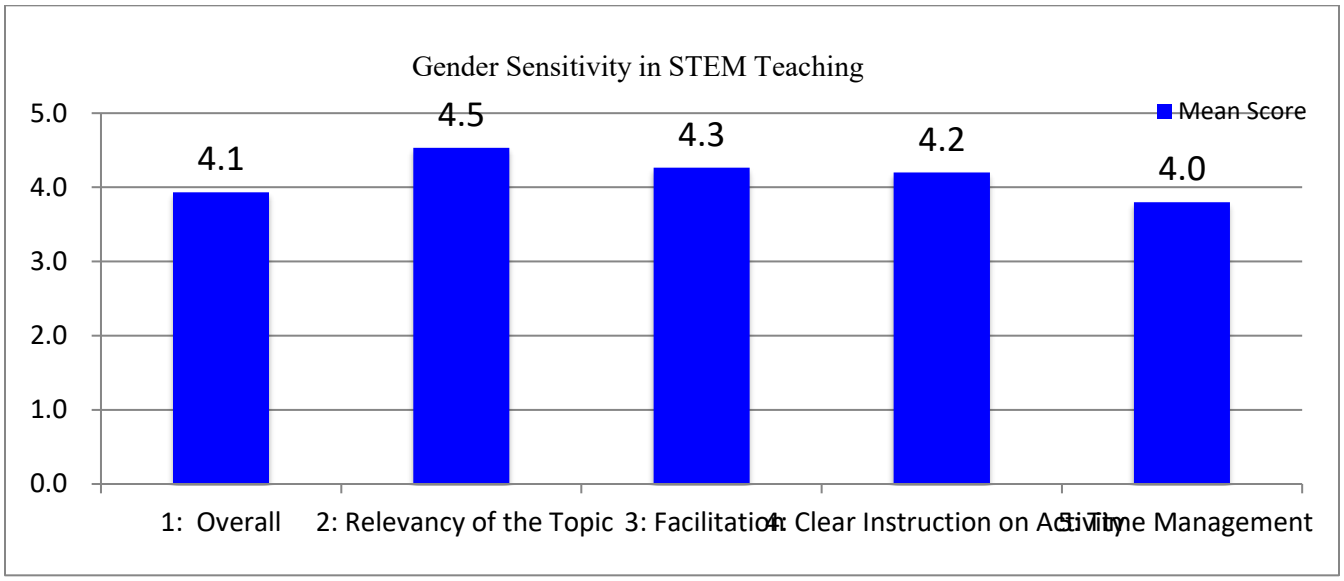
Session 3: Gender Sensitivity in STEM Teaching

The session, gender sensitivity was presented to educate the participants about the good gender sensitive attitudes expected to be deployed in the classroom by teachers to create gender balance among the students/learners for effective teaching and learning to take place for better learning outcome.

Below is the result of session evaluation administered to the participants for accessing the facilitator's performance.

Result of Question 1:

Figure 3: Quality Criteria for Gender Sensitivity in STEM Teaching



The rate on overall understanding is 4.5, i.e. satisfactory level. This implies that the facilitator delivered the message of the session on how to properly teach learners in a gender friendly classroom to promote effective learning among the learners irrespective of gender differences. Also, Facilitation skills and Time Management showed the scores of 4.3 and 3.8 in Question 3 and Question 5 respectively. Thus, participants admitted that the session was quite relevant to their profession.

Result of Question 2: Which of this session can be applied in your work?

1	All the parts of the session
2	Most parts of the sessions
3	The session was very educative.

From the table above, this indicated that participant has realized the important of this session to their in-service training. This is because all the participants provide similar opinions on the question. Such as all part and Most part of the sessions.

Result of Question 3: Which of this session is found to be difficult to understand?

	Feedback from participants
1.	None, because the session was clearly understood

The entire participants gave almost the same answer to this question because they were able to have a good understanding of the session objectives and all activities were well understood.

Result of Question 4: Any comments?

1	Very good facilitation.
2	No comment.
3	Very educative.
4	Excellent presentation.
5	The knowledge and skill participants in relation to gender sensitivity was enhanced.

Based on the participants' comments, it showed that the session was well understood.

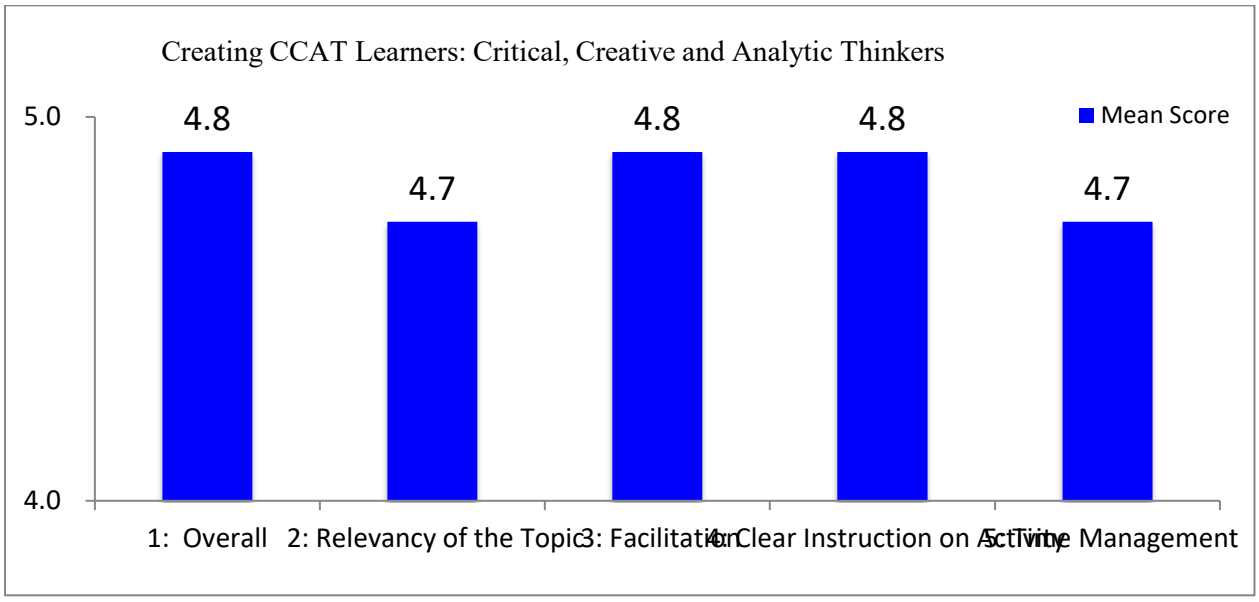
Session 4: Creating CCAT Learners (Critical, Creative and Analytic Thinkers)

Engaging learners in a variety of activities is essential to strengthening and promoting their critical, creative and analytical thinking skills. These activities encourage learners to explore new ideas, evaluate information critically, and apply logical reasoning to problem-solving. Giving learners opportunity to think in order to draw together their existing knowledge and make connections between what they already know and the problem they are thinking about, motivates them and create a sense of ownership to the whole process of teaching and learning

At the end of the session, session evaluation was administered; the result is as shown below:

Result of Question 1:

Figure 4: Quality Criteria for Creating CCAT Learners (Critical, Creative and Analytic Thinkers)



The overall rating of the session was 4.8 which showed that the targeted mean score was attained; hence the objective of the session can be said achieved. Facilitation was rated 4.8 which was an encouraging one from the side of the facilitator.

There was also a great improvement on time management as been observed.

Result of Question 2: Which of this session can be applied in your work?

1	All parts.
2	All parts because they are all relevant.
3	All parts are applicable to my work.
4	Allowing learners to think.
5.	All

Result of Question 3: Which of this session is found to be difficult to understand?

1	None.
2	The facilitator made clear and simple

3	Nil.
4	All parts were handled well
5	None, all the parts are treated well with the understanding of the facilitator.

Result of Question 4: Any comments?

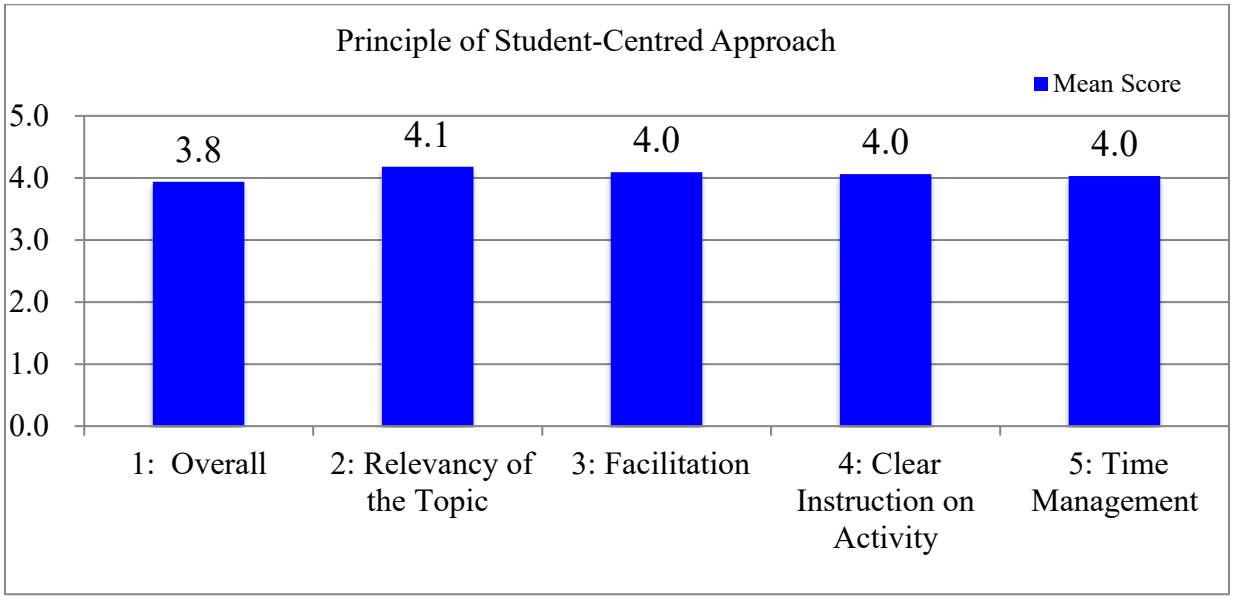
1	There should be more and more INSETs.
2	No.
3	Job well done

Session 5: Principle of Student-Centred Approach

This is the fifth session of the training. The session aimed at enabling participants to demonstrate an understanding of the principles of student-centred approach in the teaching of STEM Subjects It also serves as guide towards what is expected from the participants during the subject sessions. At the end of the session, session evaluation was administered; the result is as shown below:

Result of Question 1:

Figure 5: Quality Criteria for Principle of Student-Centred Approach



From the figure above, time management was rated 4.0 which is an indication that the facilitators were able to make good use of the time allocated to the session. Relevancy of topic and facilitation

were both scored 4.1 which is also an excellent grade. Lastly, overall assessment was rated 3.8 neutral and instruction on activity was rated above average (4.0).

Result of question 2: Which part of this session can be applied in your work? Reason(s).

1.	All parts of the session are important for one to become ASEI-PDSI compliance.
2.	Grouping. It will make the lesson easy to be impacted on the pupils.
3.	PDSI Cycle improvement, because it will help in teaching.
4.	Time management because time will not wait for me and my pupils for pupil will feel disturbed if I took them for too long.
5.	The session overall can be applied to my work because session overall was achieved.

The above table indicates that the participants found that the session is general relevant and can greatly be applied in the work (teaching and learning of science and mathematics in the classroom).

Result of Question 3: Which part of this session is found to be difficult to understand?

1.	No part
2.	None, because all were understood.
3.	Activities provided because it is difficult to source for materials.
4.	The grouping because it will take time to do that.

The above relates that the participants faced challenge with the content and usage of the checklist but after thorough explanation by the facilitators, they were able to comprehend and meaningfully understood its content and usage.

Result of Question 4: Any comments

1.	Good presentation by the facilitators.
2.	Satisfactory.
3.	It was a splendid facilitation.

The participants found the training well packaged and adequately presented.

Recommendation

Facilitators should improve in the area of session overall as well as instruction on activities.

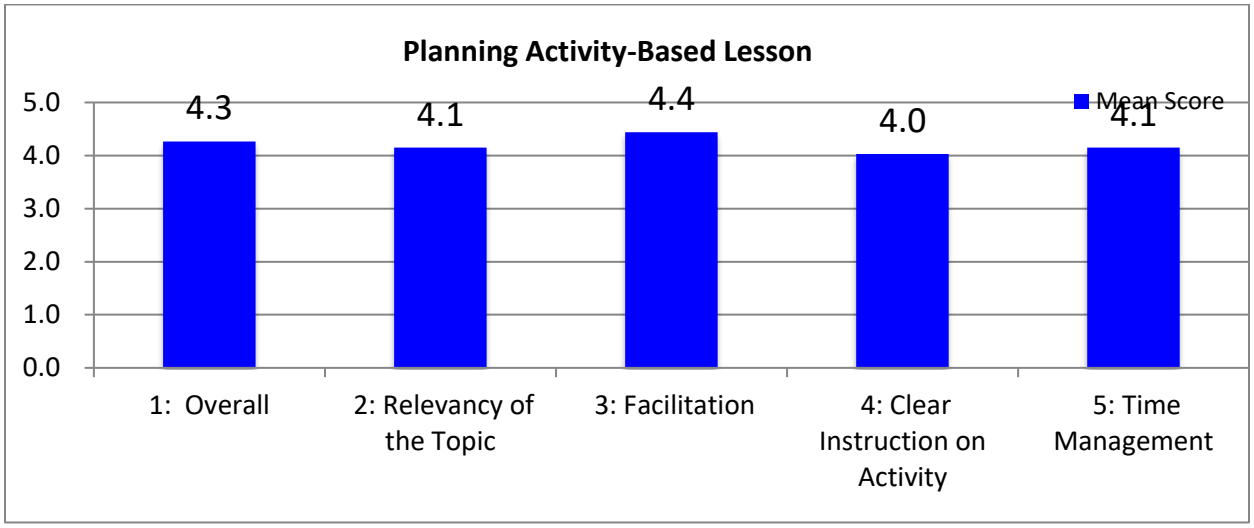
Session 6: Planning Activity-Based Lesson

This session is aimed at guiding participants to identify the features of an activity-based lesson plan as well as be able to appreciate planning of activity-based lesson in their everyday teaching.

At the end of the session, session evaluation was administered; the result is as shown below:

Result of Question 1:

Figure 6: Quality Criteria for Planning Activity-Based Lesson



The overall rating of the session was 4.7 which showed that the targeted mean score was attained hence the objective of the session was achieved. Facilitation was rated 4.7 hence the facilitator fostered learning during the session.

Result of Question 2: Which of this session can be applied in your work?

1	All aspect of the session because it is activity based and learned centered.
2	The objectives because it guides me in planning activity-based lesson.
3	All aspect of the session because it helps me to develop better activity-based lesson plan
4	The introduction because it helps me to consolidate learners' previous experiences and clarify the lesson objectives.
5	The evaluation stage because it helps me assess the attainment of the learning points as well as the stated lesson objectives by short questions, tasks and activities.

The participants demonstrated a good appreciation for the process involved in designing/planning ASEI lesson.

Result of Question 3: Which part of this session is found to be difficult to understand? Give the reasons.

1	Developing learners' activities because it involves deeper knowledge of the content, concept, improvisation of teaching/learning materials and time management.

2	Time management in improving the ASEI lesson
3	All part of the session because it is time consuming.

Result of Question 4: Any comments?

1	It is important to embrace activity-based method of teaching and learning that encourages learners to develop and create their own knowledge based on their daily experiences.
2	The session was well presented and understood.
3	The presentation was good, inspiring and rejuvenating.

From the comments above, it was observed that the participants really appreciated the session, hence planning of ASEI lessons were well appreciated by the participants.

Session 7: Improvisation of Instructional Materials for Teaching and Learning of STEM Subjects

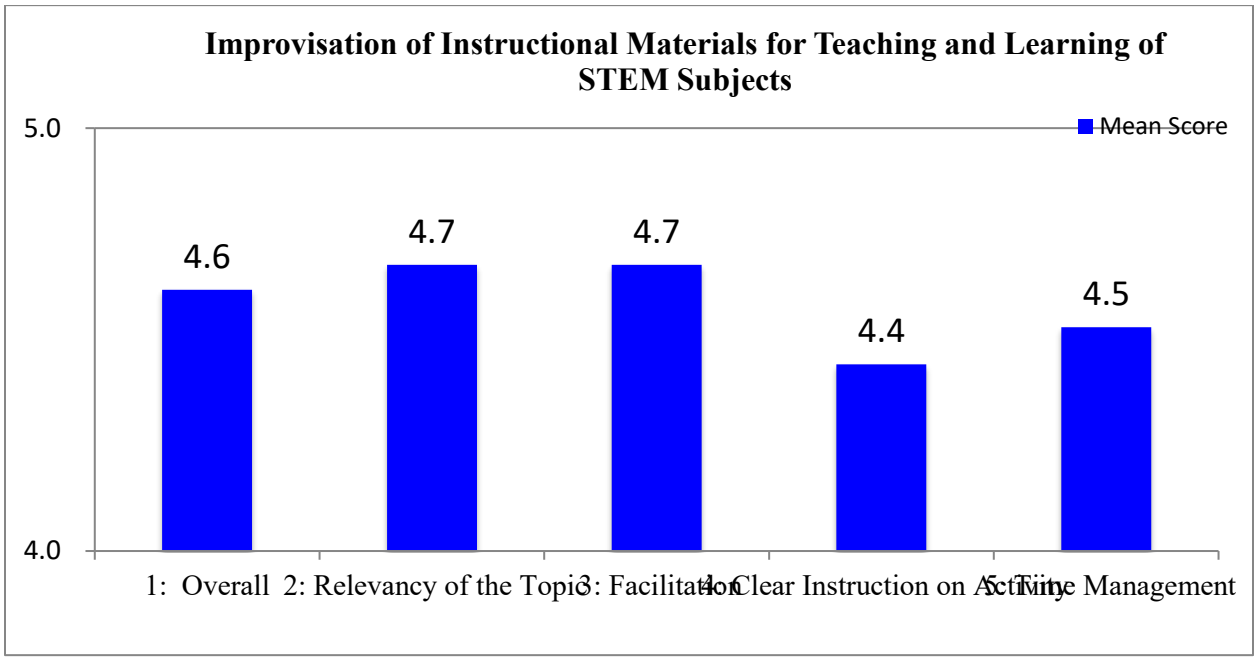
The session gives various reasons on why the improvisation of instructional materials for teaching and learning of STEM subjects is very important such as the SMASE baseline survey carried out in the three pilot states painted a gloomy picture of the state of instructional materials in the teaching and learning of STEM subjects. In addition to the survey findings, recent studies (Ajayi, 2009) blamed lack of resources and teachers' poor knowledge and skills in improvisation as culminating in poor state of STEM subjects in our schools

It is in a bid to address this sorry state of improvisation of instructional materials and consequently improve the state of STEM subjects that this session is intended.

At the end of the session, session evaluation forms were administered; the result is as shown below:

Result of Question 1:

Figure 7: Quality Criteria for Improvisation of Instructional Materials for Teaching and Learning of STEM Subjects



The overall rating of the session was 4.7 which showed that the targeted mean score was attained, hence the objective of the session were achieved. Facilitation was rated 4.7 hence the facilitator fostered learning during the session.

Result of Question 2: Which of this session can be applied in your work?

1	All aspect of the session because it shows me how to effectively Improvise teaching and learning materials by using locally available materials which can be used to teach a giving concept
2	All aspect of the session because it provides me with the skills and knowledge for improvisation
3	All the parts of the session are applicable because it helps me to be innovative and creative
4	All parts of the session because it makes teaching and learning easy and simple
5	All aspect of the session because it encourages professional development in teaching and learning

The participants demonstrated a good appreciation for the session improvisation of instructional materials for teaching and learning of STEM subjects as it equipped them with the basic skills and knowledge on how to improvise teaching and learning materials by using locally available materials which can be used to teach a giving concept in their various schools

Result of Question 3: Which part of this session is found to be difficult to understand?

1	None
2	None
3	Time management in improvisation of instructional materials for teaching and learning of STEM subjects.
4	Inadequate skills and knowledge in improvisation of instructional materials for teaching and learning of STEM subjects
5	None

From the sampled responses, participants understand and appreciate all aspect of the session improvisation of instructional materials for teaching and learning of STEM subjects as it equipped them with the basic skills and knowledge in iimprovising teaching and learning materials by using locally available materials which can be used to teach a giving concept gained during the INSET.

Result of Question 4: Any comments?

1	It is important to embrace improvisation of instructional materials as a modality for effective teaching and learning of STEM subjects.
2	The session was well presented and understood
3	The presentation was good, inspiring and rejuvenating.

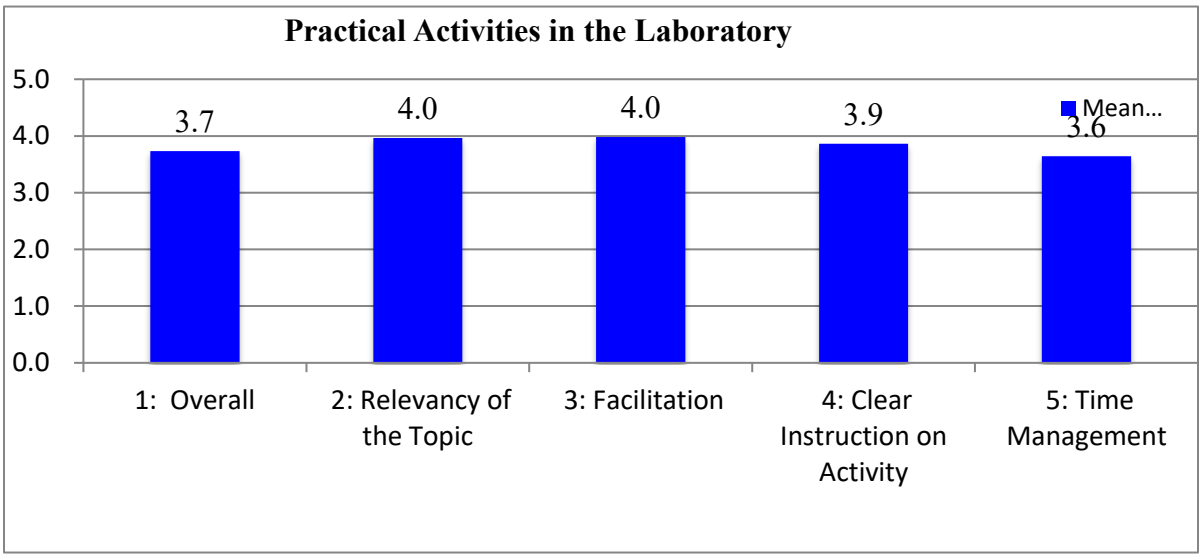
From the comments above, it was observed that the participants really appreciated the session; hence the application of improvisation of instructional materials for teaching and learning of STEM subjects will encourage innovation, creativity, production, skill acquisition and so on gained in training like this.

Session 8: Practical Activities in the Laboratory

The session was planned to enable participants to cultivate the characteristics of student-centred, activity-based teachers which include been creative and innovative with respect to bringing relevant and scale-down activities into their teaching.
At the end of the session, session evaluation forms were administered; the result is as shown below:

Result of Question 1:

Figure 8: Quality Criteria for Practical Activities in the Laboratory



The rate on relevancy of the topic and facilitation were 4.0, which is satisfactory. However, Time Management still need to be improved since the score is 3.6. Participants think that the topic and facilitation style used in this session were ok as shown in the graph above.

Result of Question 2: Which of this session can be applied in your work?

1	All parts of the session
2	All
3	Mixing the red and blue colours with hot and cold water respectively.
4	The result of the activity
5	Relating the set up to the real world

All the above comments were made due to the understanding of the session that the participants have, since it is what they have been practicing in their classrooms.

Result of Question 3: Which of this session is found to be difficult to understand?

1	None
2	The session is interesting
3	None
4	none
5	None

Result of Question 4: Any comments?

1	No comment
2	No comment
3	No comment

The participant could not make any comment because they found the session useful since they can now practice ASEI-PDSI in different ways.

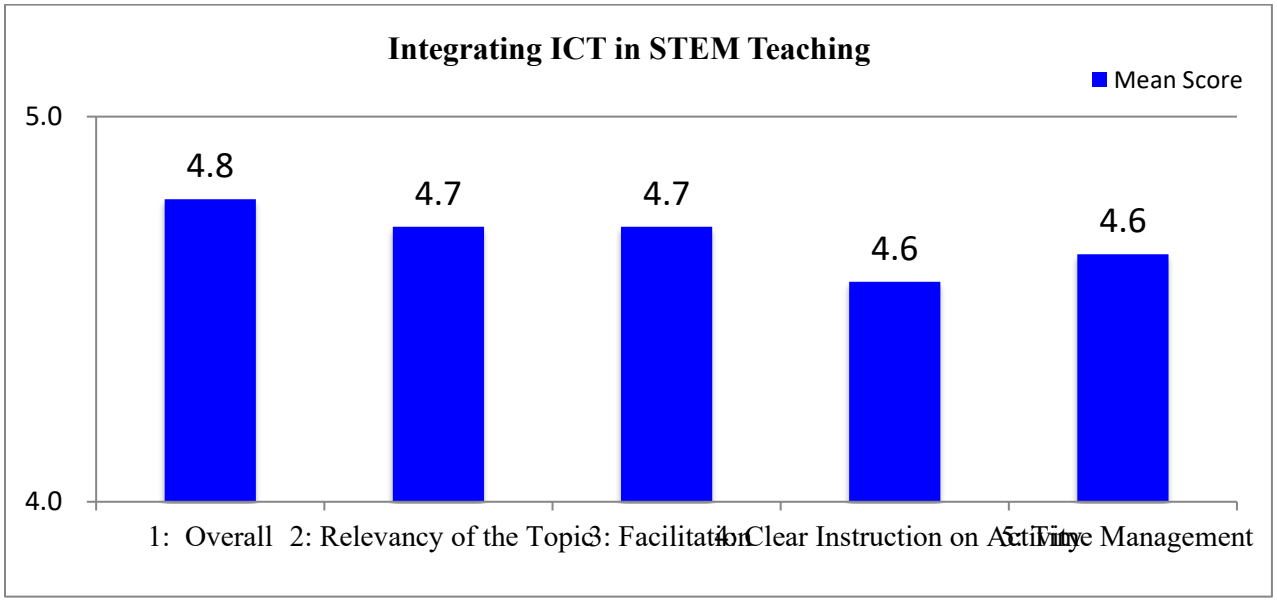
Session 9: Integrating ICT in STEM Teaching

The session was presented as an Introduction to Computer Training, to enable the participants acquire basic knowledge and skills of computer operations. The participants were able to participate actively during the session due the prior knowledge of the previous session on Integrating ICT in STEM Teaching. The session exposed them to the use of more computer application packages (Microsoft Word and Internet e.t.c.) and storage devices to enable them effectively use computer in teaching and learning process.

The below figure showed the scores of the session evaluation graphically.

Result of Question 1:

Figure 9: Quality Criteria for Integrating ICT in STEM Teaching



In the above graph, overall was rated 4.3, and it showed satisfactory of the session presented.

Relevancy of the session was rated 4.3, which indicated that, the session is relevance to participants' profession. Facilitation was rated 4.5, thus, it indicated that, the facilitator has presented the session satisfactorily. The rate of clear instructions on activity was rated 4.4, and it showed that, the instructions given for the activities were understood, and the participants were able to carry out the activities accordingly. Time management was rated 4.5, it indicated that, the time was properly managed, and the participants were able to carry out the activities within the given time. The facilitator managed the time properly, and the session ended successfully.

Result of Question 2: Which of this session can be applied in your work?

1	All.
2	All the sessions can be applied
3	All the parts of the session
4	All are applicable to teaching and learning

Result of Question 3: Which of this session is found to be difficult to understand?

1	Microsoft excel
2	None of the parts
3	None of the session is difficult
4	Opening a file and saving file
5	No session was difficult

Result of Question 4: Any comments?

1	Computer training should be continued in the subsequent training
2	Good facilitation
3	Excellent facilitation

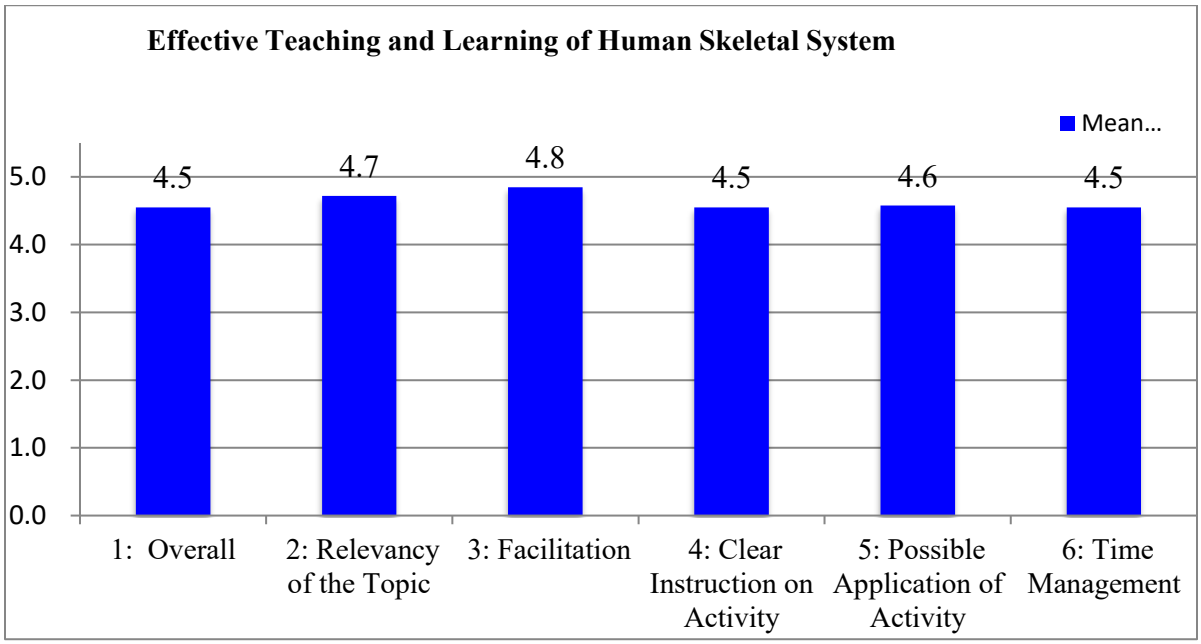
The session ended successfully, and most of the participants were able to understand the session, because it was presented well. More instructions on activity will be given in subsequent training on the identified areas by the participants to enable them understand better.

Session 10: Effective teaching and learning of Human Skeletal System (Basic Science)

This session has been planned to address some of the challenges found to be facing teachers and pupils in the teaching and learning of the topic Human Skeletal System.
The below figure showed the scores of the session evaluation graphically.

Result of Question 1:

Figure 10: Quality Criteria for Effective teaching and learning of Human Skeletal System



Understanding of the overall session was rated 4.5, which is satisfactory level. Relevancy of the topic, level of facilitation and instruction on activity were rated 4.7, 4.8 and 4.5 which were all above average. Time management in the session and possible application of the session's activity as seen above were rated 4.5 and 4,6 respectively.

Result of Question 2: Which of this session can be applied in your work?

1	All
2	All
3	Relevant activities
4	Partially
5	Time management

Result of Question 3: Which of this session is found to be difficult to understand?

1	None
2	None
3	None
4	None
5	None

Result of Question 4: Any comments?

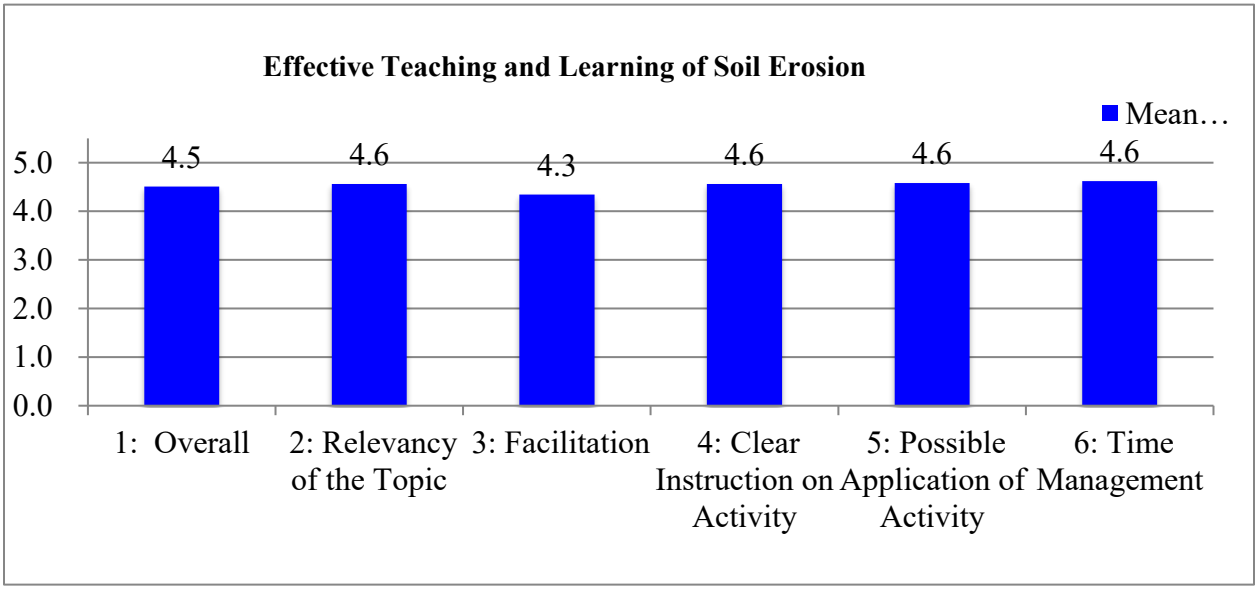
1	Facilitation was good
2	Satisfactory
3	Well done

Session 11: Effective teaching and learning of Soil Erosion (Agricultural Science)

Effective strategy of teaching and learning of soil erosion was planned to enhance the teachers' pedagogical skills, concept mastery and geared toward achievement of the set goal of the SMASE INSET programme. Moreover, it also to educate the participants on new learner-centred and how to create suitable activities that make the retention more permanent and interesting.
The below figure showed the scores of the session evaluation graphically.

Result of Question 1:

Figure 11: Quality Criteria for Effective teaching and learning of Soil Erosion



The topic is relevant to the participants. Facilitation skills were scored 4.3 this means that the facilitator conveyed the message of this session in a proper way and participants received and it

was understood. However, while clear instruction activity, possible application of the activity and time management were scored 4.6 each which were also satisfactory. The score needs to be improved to reach the maximum score (5.0) of the instrument in the subsequent sessions. Participants think that this session is relevant to their lessons and that the activities shown in this session helps the improvement of their teaching methods of this session in their classrooms.

Result of Question 2: Which of this session can be applied in your work?

1	All the parts of the session
2	Most parts of the sessions
3	Almost all of the session
4	Some parts are not so easy to apply

Result of Question 3: Which of this session is found to be difficult to understand?

1	None, because the session was clearly explained
2	The activity for controlling soil erosion
3	Relating activities to real life situation

Result of Question 4: Any comments?

1	No comment
2	More examples of use of diagram should be introduced
3	Improvement is required in the group for better actualization in our schools
4	There should be refresher training from time to time
5	There should be routine practical training for the SMASE

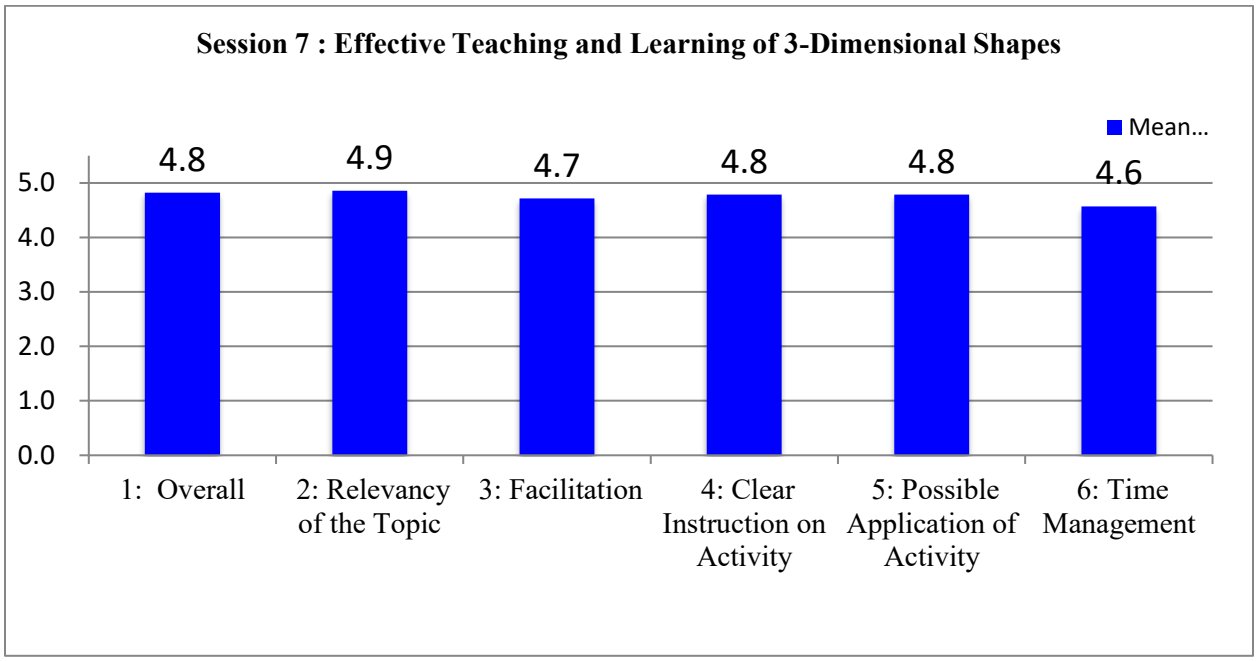
Session 12: Effective Teaching and Learning of 3-Dimensional Shapes

The concept of 3-Dimensional Shapes is an important area of study and it is applicable to our daily life. However, baseline survey (2006) showed that 40.5% of learners and 41.3% of teachers find the learning and teaching of 3-dimensional shapes difficult in our schools. Hence, the need for the Teacher to be skilful in planning a better ASEI Lesson Plan on the concept using hands-on activities and simple diagrams to visualise 3-dimensional shapes in order to help learners understand the concept better. This session is designed to enhance the ability of teachers to adequately prepare and deliver an activity- based/learner centred lesson on the topic.

At the end of the session, session evaluation questionnaire was administered and the results are shown below:

Result of Question 1:

Figure 12: Quality Criteria for Teaching and Learning of 3-Dimensional Shapes



The rate on overall understanding is 4.8, i.e. satisfactory level. This implies that the facilitators conveyed the messages of this session in a proper ways and participants received it accordingly. Also, Facilitation skills and Time Management also show scores of 4.7 and 4.6 in Question 3 and Question 6 respectively. Participants believed that this session is relevant to their classroom activities. Also, the activities involved in this session will effectively help in teaching and learning of the concept.

Result of Question 2: Which of this session can be applied in your work?

1	All parts of the session
2	Most parts of the sessions

Result of Question 3: Which of this session is found to be difficult to understand?

1.	None, because the session was clearly understood.
2.	Designing of worksheet/activity sheet that will ease the work of the teacher.

Result of Question 4: Any comments?

1	ASEI-PDSI approach is the best for teaching mathematics and science
2	Very good session and interesting
3	An improved presentation

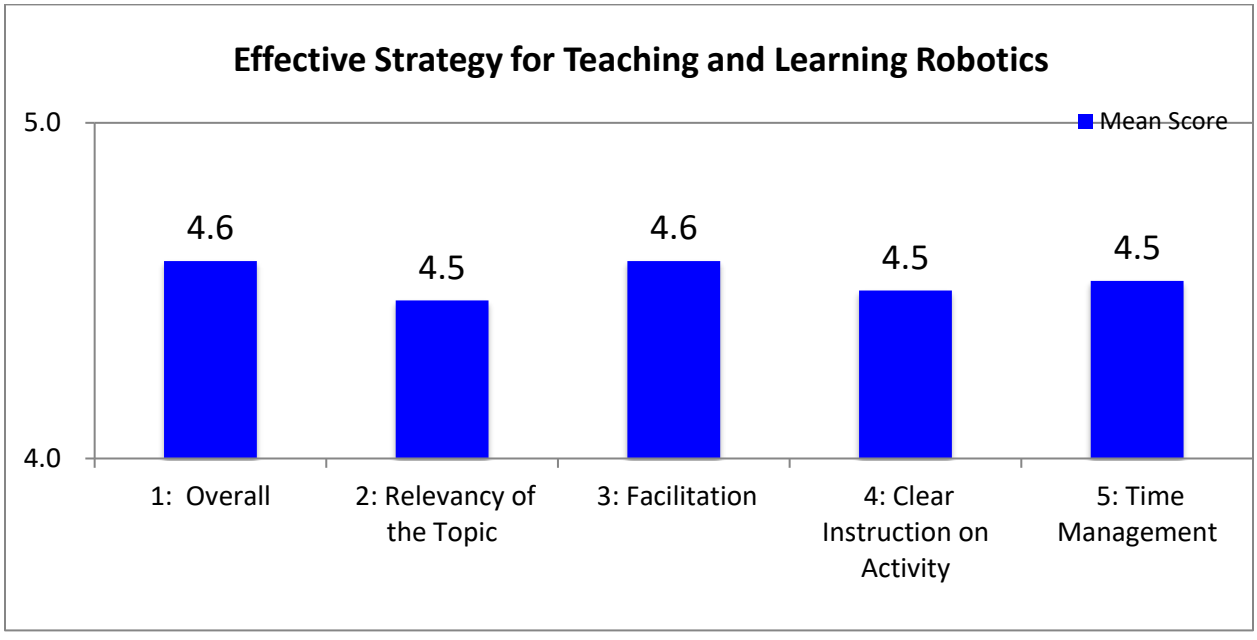
Session13: Effective strategy for teaching and learning Robotics.

The importance of robots in the modern age cannot be overemphasized. It cuts across various disciplines Science, Technology, Engineering, Mathematics (STEM), Agriculture, Medicine, Education, etcetera, making work easy and it aids in performing tasks with precision. In order to prepare learners to function effectively in our society and in the modern world and use robots to ease their daily activities, they need to be exposed to the skills and knowledge of Robotics. The objectives of the session were to Identify the challenges in teaching the concept, suggest a way forward and to build a simple robot for use in the field of Agriculture and the objectives of the session were achieved.

At the end of the session, session evaluation was administered; the result is as shown below:

Result of Question 1:

Figure 13: Quality Criteria Effective Strategy for Teaching and Learning Robotics



The overall rating of the session was 4.6 indicating that the targeted mean score was attained which

led to the achievement of the overall objective of the session. Facilitation was rated 4.6 which indicated that learning was enhanced during the session.

Result of Question 2: Which of this session can be applied in your work?

1	Technology – this is because we are in a technological era where computers can be used to perform so many tasks within a short time frame.
2	All parts of the session. I have a basic understanding of robotics and its use.
3	How robotics can be used in farming/Agriculture.

Result of Question 3: Which part of this session is found to be difficult to understand?

1	None.
2	No part.

Result of Question 4: Any comments?

1	I thank the facilitator for a well delivered session.
2	The session is impactful in appreciating the everyday use of Science, Technology, Engineering, Mathematics and Agriculture.
3	None.

4. Impact Of the STEM Training Programme

Enhanced Teaching Skills: The programme has equipped teachers with advanced STEM teaching skills, enabling them to deliver high-quality education in Science, Technology, Engineering, and Mathematics (STEM) subjects.

Improved Learning Outcomes: Teachers trained through the programme have reported they are expecting improved student engagement and performance in STEM subjects.

Capacity Building: The programme has contributed to the professional development and capacity building of teachers, empowering them to deliver effective STEM education.

Sustainable Impact: By investing in teacher training and development, the programme has laid the foundation for sustainable improvements in STEM education within Kudan LGA, Kaduna

State.

5. Recommendation for further study

1. Conduct extended research over multiple academic years to assess the long-term impact of the SMASE Practical Approach on both teaching practices and student performance in STEM subjects.
2. Compare the effectiveness of the SMASE Practical Approach with other pedagogical methods in different regions or educational settings to identify best practices and potential areas for improvement.
3. Investigate the role of resource availability and teacher training in the successful implementation of practical approaches. This could include evaluating the types of resources that most significantly enhance STEM education and developing comprehensive training programs for educators.
4. Explore how the SMASE approach affects other student outcomes beyond academic performance, such as critical thinking skills, creativity, collaboration abilities, and interest in pursuing STEM careers.
5. Examine how integrating modern educational technologies with the SMASE Practical Approach can further enhance STEM teaching and learning experiences.
6. Assess the feasibility of scaling the SMASE Practical Approach to other LGAs within Kaduna State or different regions in Nigeria. This includes studying how adaptable the approach is to diverse educational contexts and varying resource levels.
7. Analyze how findings from such studies can inform educational policies and curriculum development at the local and state levels to support effective STEM education initiatives.
8. Investigate the impact of involving parents and the wider community in STEM education through the SMASE approach, potentially enhancing support systems for students and reinforcing the importance of STEM learning.

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Article 6

Impact of Continuous Professional Development on Rwandan Mathematics and Science Teachers' Proficiency in Utilizing Modernized Instructional Tools and Innovative Pedagogy.

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Abstract

The present study assesses the impact of the Rwanda Quality Basic Education for Human Capital Development (RQBEHCD) project on Mathematics and Science education in Rwanda. The project emphasizes continuous professional development in Innovative Teaching Mathematics and Science (CPD-ITMS) for teachers from upper primary to lower secondary levels. The CPD focuses on enhancing teachers' proficiency in utilizing modern instructional tools in teaching Mathematics and Science and their proficiency in using innovative pedagogies, particularly the 5Es instructional model (Engage, Explore, Explain, Elaborate, Evaluate). The research used a mixed-methods approach, incorporating classroom observations and semi-structured interviews, with a sample of 62 teachers. The study highlights the effective use of modern instructional tools. Particularly, 81% of the observed teachers use the provided projectors and computers. Additionally, the study revealed that 59% of teachers use scripted lessons in teaching while a considerable number around 41% of teachers did not use scripted lessons in their teaching. Most importantly, the findings indicated that 90% of the teachers who use scripted lessons are able to use them effectively and completely. In addition, the findings showed a high adoption rate of the 5Es model (84%), with the elaborate phase being the least implemented. The results from interviews indicated some teachers' challenges in implementing the skills from CPD-ITMS such as *lack of and poor internet*

connection, lack of electricity in the classrooms, Unsupportive school leaders, not to mention a few. This study recommends a thorough follow-up and sensitization at the school level to ensure the effectiveness of CPD programs in improving educational outcomes in Rwanda.

Key words: CPD-ITMS, modernized instructional tools, innovative pedagogy, teachers' proficiency, 5Es.

1. Introduction

In the global pursuit of economic growth and innovation, education is universally recognized as a fundamental driver of development (World Bank, 2018). Nations aiming to transition into knowledge-based economies increasingly emphasize the importance of cultivating proficiency in key disciplines such as mathematics and science. This emphasis is particularly crucial as these subjects form the backbone of technological advancement and skilled labor. In line with this global trend, Rwanda recognizes the pivotal role that education plays in shaping its future (Yongabo, 2021; MINEDUC, 2017). Emphasizing competence in subjects like mathematics and science is crucial to nurturing a generation of skilled individuals who can contribute meaningfully to the nation's development. Central to this endeavor is the understanding that teachers are the architects of knowledge, guiding students towards proficiency.

Consequently, the commitment to providing continuous professional development for teachers becomes paramount, ensuring that they possess the requisite knowledge and skills to effectively support their students in the realms of Mathematics and Science. Certainly, teachers' proficiency is a paramount factor influencing students' learning, surpassing the impact of social and demographic variables, as highlighted by Hanushek (2014). Specifically, the direct correlation between teachers' competence knowledge and students' performance and interest in specific subjects have been substantiated in studies by Blazar and Kraft (2017), Hill et al. (2008), and Keller et al. (2017).

Competence, however, is not an inherent trait but a skill honed over time, as emphasized by Bandura (2001) and Dorsey & Patterson (2018). Therefore, there is a pressing need to equip teachers with enhanced professional support to continually refine and update their content and pedagogical knowledge (CPK). The strategic investment in mathematics and science teachers' professional development not only fortifies the educational landscape but also lays the foundation for a sustainable and knowledge-driven economy in Rwanda. In alignment with this vision, the Government of Rwanda, through the Ministry of Education (MINEDUC) and the Rwanda Basic Education Board (REB), has undertaken the implementation of the "Rwanda Quality Basic Education for Human Capital Development" (RQBEHCD) project, Sub-component 1.2 (Worldbank, 2019). This sub-component is dedicated to supporting professional development of mathematics and science teachers from Primary four to senior three in Rwandan schools through

a Continuous Professional Development in Innovative Teaching of Mathematics and Science (CPD-ITMS) certified program (Worldbank, 2019). The University of Rwanda College of Education (UR-CE) is a key partner in the execution of this project.

The primary objective of Sub-component 1.2 is to elevate students' learning gain in basic education by bolstering the professional development of Mathematics and Science teachers. The heart of the project initiative lies in its commitment to providing continuous professional training for Mathematics teachers recognizing the transformative potential of innovative teaching methodologies. The project places a particular emphasis on equipping teachers with innovative pedagogical approaches where among these approaches, the adoption of the 5Es model in teaching Mathematics and Science has been highlighted, reflecting a commitment to engage, explore, explain, elaborate, and evaluate in the teaching and learning process.

The provision of continuous professional development and modernizing instructional tools are the cornerstone of all the activities undertaken by RQBEHCD Sub-Component 1.2. to empower educators in their teaching activities. Within this framework, mathematics and science teachers from upper primary (P4-P6) to lower secondary (S1-S3) have been equipped with cutting-edge resources, including projectors, laptops, and formative assessment tools such as plickers, voting cards, and show me boards. In additions, the project has developed the scripted lessons of all lessons in mathematics and science subjects from P4-S3 and availed them for teachers and students use. Indeed, these tools are instrumental in creating dynamic and interactive learning environments, fostering student engagement and participatory learning.

Considering the significance of hands-on learning experiences in Science and Mathematics education, the project has also supplied teachers with science kits. These kits are designed to facilitate practical demonstrations, experiments, and different practical works, thereby enhancing the understanding of abstract concepts and promoting a deeper comprehension of scientific principles. Researchers DeCoito & Myszkal (2018) highlight a strong link between hands-on science teaching and teachers' self-efficacy, aligning with Bandura's self-efficacy theory. This theory suggests that confidence in one's abilities enhances his performance Bandura (1999). In teaching, hands-on activities not only boost student engagement and understanding but also reinforce teachers' confidence in their methods. As teachers see positive outcomes, their self-efficacy grows, encouraging the continued use of innovative teaching strategies and tools, creating a positive cycle of effective teaching and learning.

1.1.Objective of the study

1. Evaluate the extent to which trained teacher implement innovative pedagogy (5Es model) in teaching Mathematics and Science.

2. To assess the level and proficiency of mathematics and science teachers in using the provided modernized instructional tools (computer and projectors, scripted lessons, math and science kits, formative assessment tools)

1.2.Research questions

1. To what extent do trained teachers implement the 5Es model of innovative pedagogy in teaching Mathematics and Science?
2. What is the proficiency level of Mathematics and Science teachers in using modernized instructional tools (such as computers, projectors, scripted lessons, math and science kits, and formative assessment tools)?

2. Methodology

2.1.Population and Sample

The target population for subcomponent 1.2 are mathematics and science teachers from 16 districts of the RQBEHCD Sub-Component 1.2. intervention who successfully completed the trainings provided by the Rwanda quality basic Education for Human Capital Development Project Sub-Component 1.2. Among 2775 mathematics and science teachers who completed the training, a sample of 44 teachers was chosen where among them 18 were School Subject Leaders (SSLs). The SSLs are the teachers who in addition to completing CPD-ITMS training, completed the training on coaching and mentoring and on Community of Practice. The participants in the study were selected purposefully to ensure a diverse representation across provinces, school location, subjects and gender. This approach aimed to capture a comprehensive view of the impact of the training on innovative pedagogy and the provided modernized instructional materials across various schools.

2.2. Research Design

In the course of conducting a short-term impact assessment of the project's interventions for mathematics and science teachers, the present study used a mixed research approach. Both quantitative and qualitative data were collected from the participants. Quantitative data were collected using classroom observation while qualitative data were collected by using interview guide. The phase of classroom observation involved a sample of 43 teachers who attended Continuous professional development in Innovative Teaching of Mathematics and Science (CPD-ITMS) program. This phase facilitated a meticulous examination of whether the materials provided by the project were being used effectively in the teaching and learning processes of Mathematics and Science. Simultaneously, the phase enabled the observation of teachers' adherence to innovative methodologies they have been trained on. By directly observing classroom dynamics, this approach sought to provide tangible insights into the practical use of modernized instructional tools provided and the application of innovative teaching methods by teachers.

In conjunction with classroom observations, an interview component was incorporated into the research design. This phase involved 17 teachers who in addition to completing CPD-ITMS

program, attended the training on coaching and mentoring and community of practices. Through interviews with these teachers, the focus extended beyond the mere utilization of materials and methodologies, delving into the intricacies of material maintenance and peer support. Teachers were probed on how they maintained and managed the provided materials, shedding light on the sustainability and care taken to preserve the longevity of the provided educational resources. Additionally, the interviews explored the support mechanisms employed by teachers in aiding their colleagues who had not undergone the training. This holistic approach aimed to capture not only the immediate impact within individual classrooms but also the ripple effect of knowledge transfers and collaborative practices among educators. Together, these methods furnished a nuanced understanding of the project's influence on both individual teaching practices and the broader professional dynamics among teachers.

2.3. Instruments for Data Collection

2.3.1. Classroom Observation for Mathematics and Science Teachers in CPD-ITMS

The study employed classroom observation to evaluate the extent to which trained mathematics and science teachers utilize the modernized instructional materials provided by the project and to what extent they implement the innovative teaching methodologies in teaching process. This instrument was made of six main parts: Part 1 was about Identification of the school, part 2 was part 3 is identification of the observed class and lesson, part four concerns with the lesson plan and delivery, part five consists questions that items that help to observe the Cross-Cutting Aspects of the lesson (these are aspects that are to be considered and assessed throughout all parts of the lesson: introduction, development and conclusion) and while part six items help to assess the use of modernized instructional tools package Provided by REB Through QBEHCD sub-component 1.2 to teach Mathematics and Science subjects. This was digitalized using Kobotoolbox for mare about it refer to https://ee.kobotoolbox.org/x/fxSIxLve

2.3.2. Semi-Structured Interview for School Subject Leaders (SSLs)

The decision to use interviews was guided by the need for in-depth, qualitative responses from trained who are directly involved in the implementation of modernized instructional materials and who are in supposed to support their peers at their schools. Semi-structured interviews were selected to strike a balance between a standardized framework and the flexibility to explore emergent themes during the conversations. The interview guide was formed by 10 questions.

2.4. Data Analysis

The quantitative data collected by using classroom observation for mathematics and science teachers who successfully completed CPD-ITMS program were analyzed descriptively through the use of excel-16 and SPPSS 25.0 while the data collected by the use of semi-structured

interviews from STEM school subject leaders were analyzed thematically through the use NVIVO software.

3. Findings

This section reports the quantitative findings about the current mathematics teachers' level of using 5Es instructional model in teaching Mathematics and Science. The findings also indicate the teachers' level of using modernized instructional tools that have been provided to them to enhance the teaching and learning of Mathematics and Science. This section also reports the qualitative findings from SSLs interviews

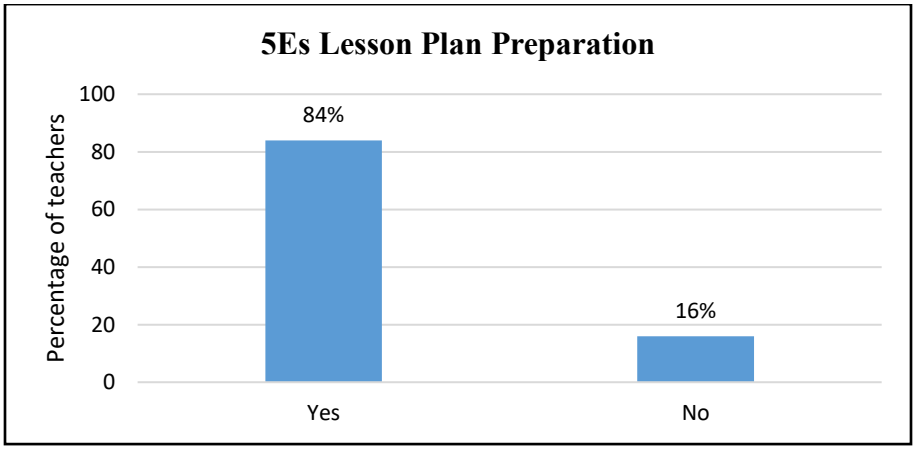


Figure 1:Teachers' proficiency in preparing 5Es lesson plan

The analysis of all phases (engage or excite, explore, explain, elaborate, and evaluate) of 5Es instructional also shows positive application of this approach in teaching mathematics and science. The following figures shows how teachers implement each phase of 5Es instructional model in teaching mathematics and science

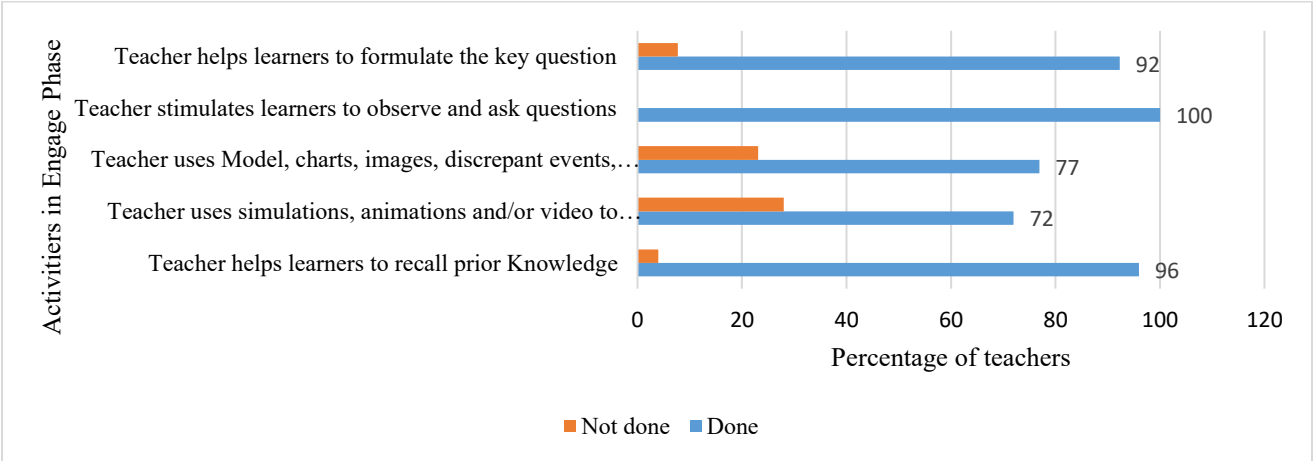


Figure 2:Strategies used by mathematics and Science to engage /excite learners

Explore phase

During the classroom observation of mathematics and science teachers on the use of the 5Es instructional model in the Explore step, nearly all teachers (99%) were able to identify the misconceptions students have on the subject topic through discussion and activities. All teachers (100%) facilitated discussions where students could share their thoughts, observations, and ideas. The majority of teachers (80%) provided hands-on activities, experiments, or demonstrations that allowed students to interact with the material in a concrete way. Additionally, 91% of teachers used multimedia resources such as videos, and animations to help students explore the topic. Finally, all teachers (100%) encouraged students to explore the topic independently or in small groups and helped them to make initial predictions or formulate hypotheses.

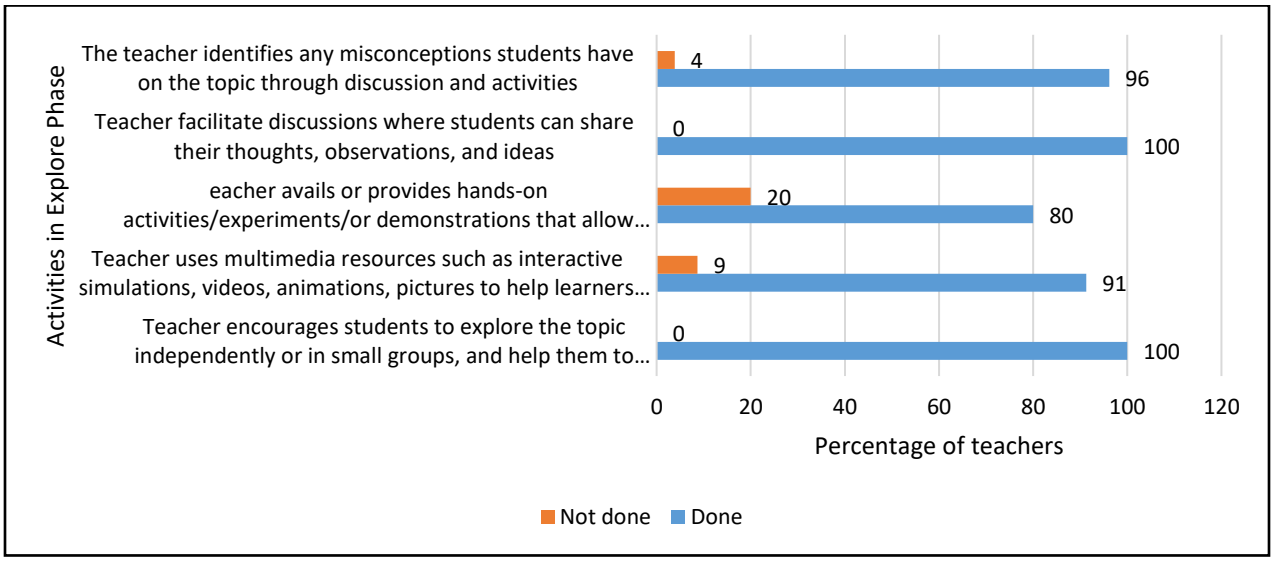


Figure 3:Strategies used by mathematics and Science during explore phase

Explain Phase

In the Explain phase of the 5Es instructional model, the observed practices of mathematics and science teachers revealed a commitment to fostering comprehensive understanding among students. Remarkably, 100% of teachers were consistently successful in inspiring learners to articulate and share their investigations and ideas in their own words, emphasizing a student-centric approach. Visual aids played a pivotal role, with 96% of teachers utilizing diagrams, charts, graphs, models, and other visual tools to enhance the understanding of key concepts, underscoring a visual reinforcement strategy. Additionally, 92% of teachers skillfully employed probing and guiding questions to facilitate connections between new information or observations and students' prior knowledge. Finally, in a proactive approach, all teachers, at 100%, addressed and corrected any misconceptions identified during the lesson.

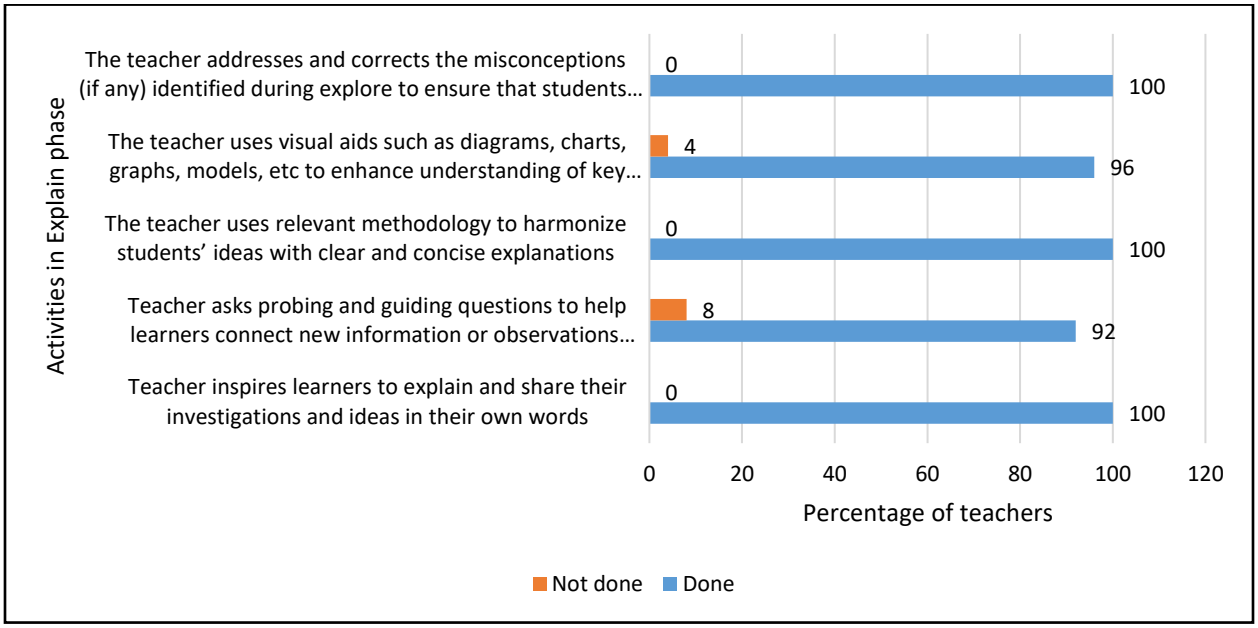


Figure 4:Strategies used by mathematics and Science during explain phase

Elaborate phase

In the Elaborate phase, most teachers (92%) effectively encouraged students to delve deeper by conducting further research on presented problems. While 78% provided additional explanations to solidify understanding, some (22%) missed this opportunity. Notably, 92% of teachers empowered students to apply their learning by analyzing and solving real-world problems related to the taught concepts. While the majority (88%) successfully integrated real-world scenarios and asked relevant questions, a smaller portion (12%) did not utilize this valuable strategy.

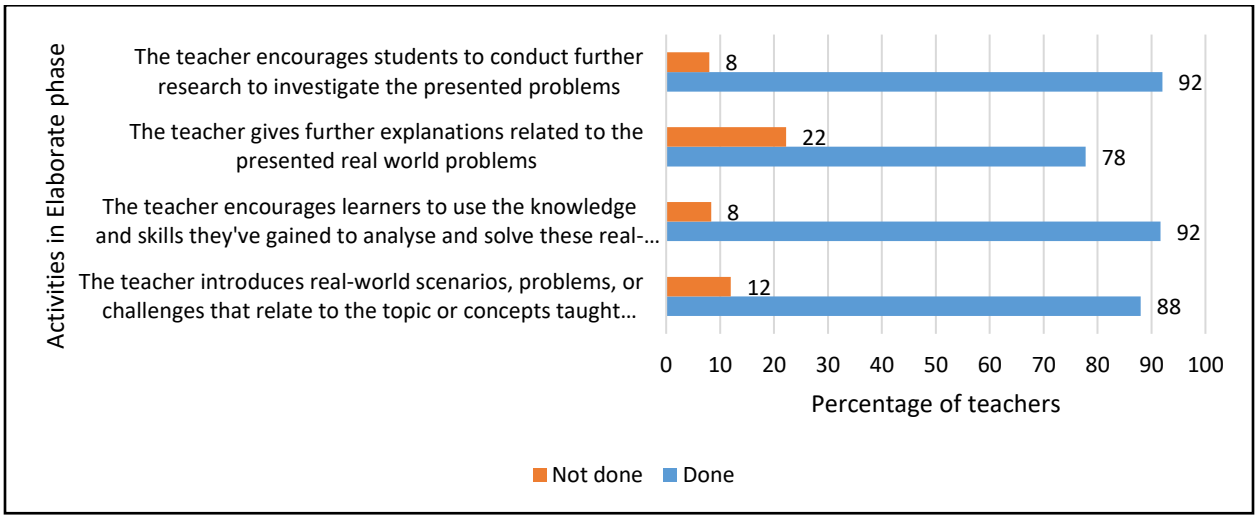


Figure 5: Strategies used by mathematics and Science during elaborate phase

Evaluate

In evaluate phase, all teachers (100%) demonstrated a positive achievement during summarizing the lesson, give students timely feedback, assess the activities that are inclusive to cater for the learners' need, and give students assessment that are align with the content and learning objectives

3.2.Teachers' Level of Using the Provided Modernized Instructional Tools

In evaluating mathematics and science teachers' level of using the provided modernized tools to enhance teaching methodologies, this report delves into the extent to which mathematics and science teachers have embraced modernized tools, including projectors, laptops, scripted lessons, and formative assessment tools, in their lessons. The overall results showed that teachers used the provided modernized assessment at the percentage of 69%. The integration of such technological and instructional resources has the potential to significantly impact the teaching experiences. By examining the utilization of these tools, we aim to gain insights into the evolving dynamics of the educational environment and identify opportunities for further enhancement and innovation in mathematics and science education.

3.2.1. Teachers' proficiency in using Computer and Projector in teaching

The findings in the Figure 7 from the classroom observation on the utilization of modern tools, specifically projectors and computers, among mathematics and science teachers revealed a substantial integration of technology in teaching practices. A notable 81% of the observed teachers employed both projectors and computers as part of their instructional tools in presentations of interactive simulations, or other digital resources. However, it is noteworthy that 19% of teachers did not utilize these tools. *The major reason provided by teachers is that some computers are not working and need to be repaired.*

After observing the extent of using computer and projector in mathematics and science lesson, we looked whether teachers used those tools in effective way and found that most teachers who use them, are able to connect the projector to their computer for projecting their teaching content very effectively and effectively at the percentage of 71% and 7% respectively, while 22% were found not able to do so in effective way. The lessons of the latter were disturbed by need of assistance in fixing projections issues.

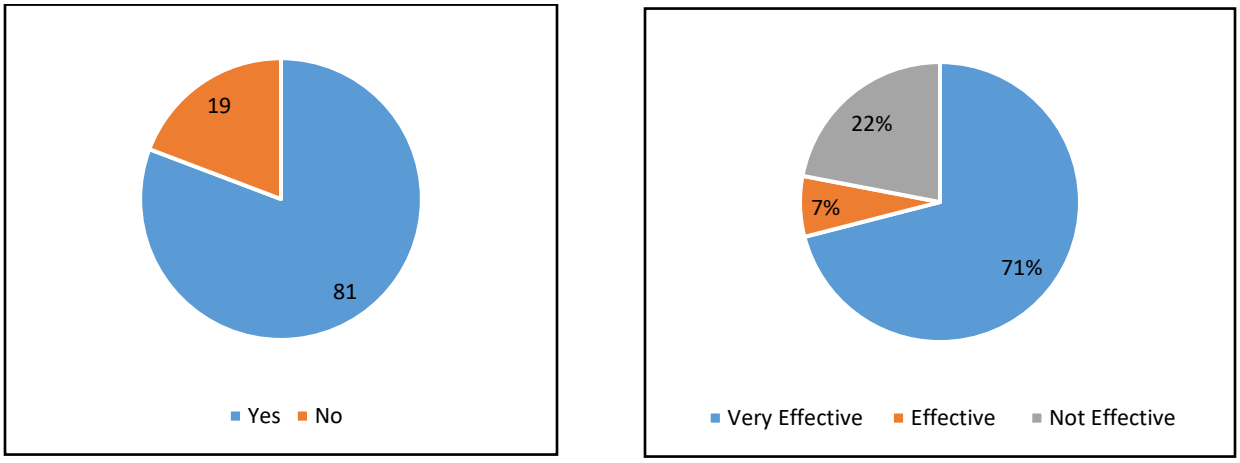


Figure 6:Mathematics and science teachers' level and proficiency of using computer and projector

3.2.2. Teachers' Level of Using Scripted lessons

The outcomes of the classroom observation focusing on the utilization of scripted lessons in mathematics and science instruction among teachers revealed that 59% use scripted lessons in teaching while a considerable number 41% of teachers did not use scripted lessons in their teaching. In this context, the major reason provided by the teachers who were not using the scripted lesson was that ***their computers are not working, lack of internet connection, and some of them they do not have access to MS 365***. After evaluating the level of using the scripted lesson, we assessed if those who used them in teaching use them completely or partially. The results highlighted that 90% of those who use them in teaching, use them completely while 10% used scripted lesson partially

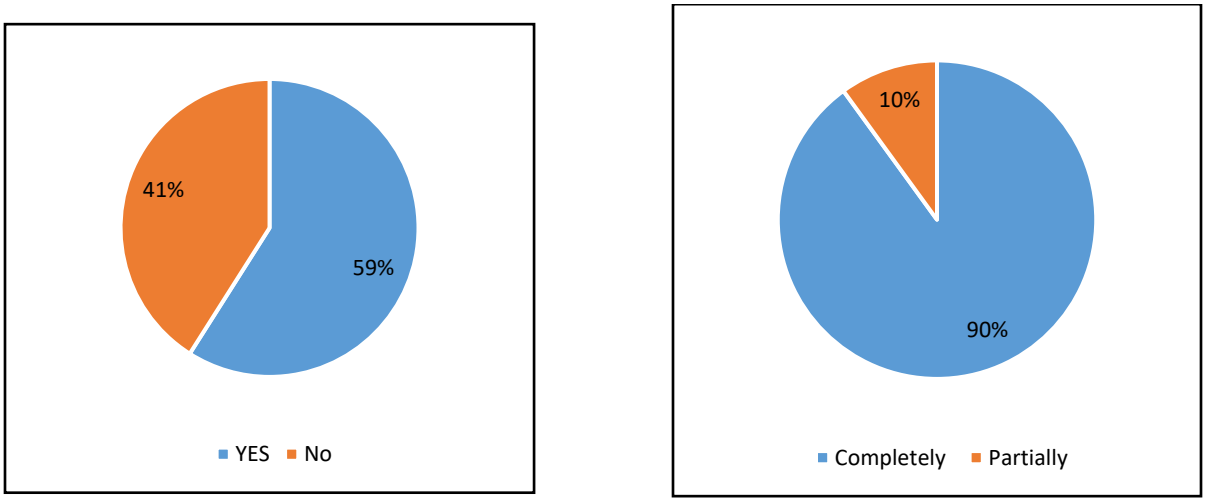


Figure 7: Mathematics and science teachers' level of using scripted lesson

3.2.3. Teacher's level of Using Mathematics and Science Kits

The overall results showed that mathematics and science teachers used the provided science kits at the percentage of 60% while 40% of them did not use those kits. It was found that those kits were used mainly during practical work and lesson demonstration. In this context, teachers explained that they did not use mathematics and science kits because some materials were damaged while others report that they used by other teachers in the school. The outcomes of the classroom observation focused on the use of mathematics and science kits by mathematics and science teachers indicate a high level of capability, with 82% of teachers deemed extremely capable in utilizing these instructional resources. However, it is noteworthy that 6% are perceived as only averagely capable, and 12% are identified as needing more training in this regard.

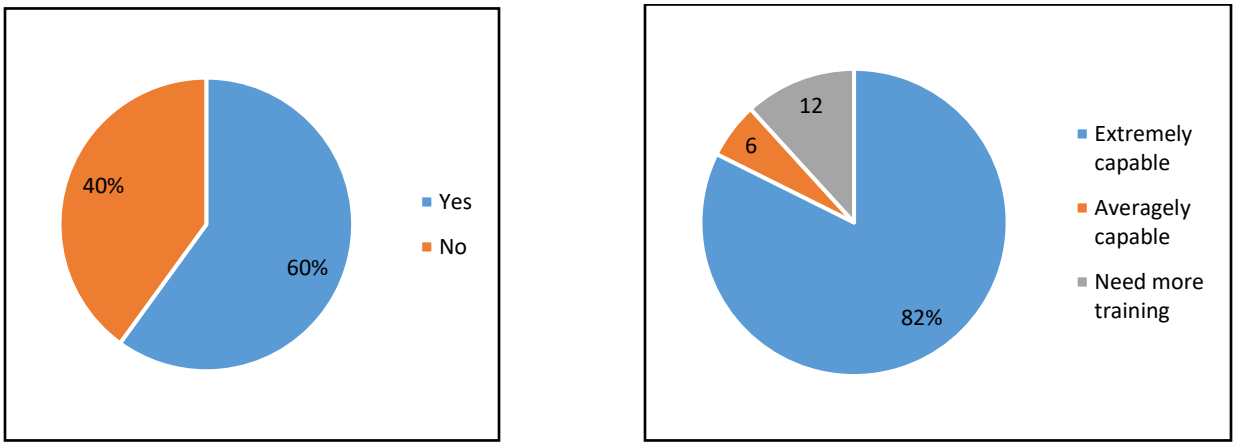
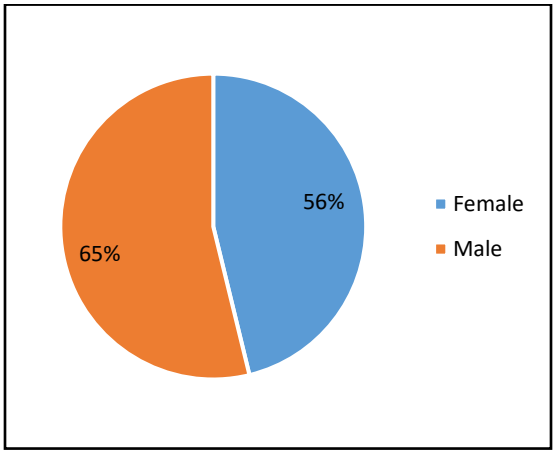


Figure 8: Mathematics and science teachers' level and capability of sing mathematics and science kits

Teachers' level of Using Mathematics and Science Kits Based on gender and school location.

the findings illustrated that male teachers used science kits more than female teachers at the percentage of 65% compared to counterparts who use those kits at the average of 56%. On the other side, based on the school geographical location, the findings showed that most schools in rural area used more mathematics and science kits at the average 73% compared with the schools in the urban area which used these kits at the average 53%



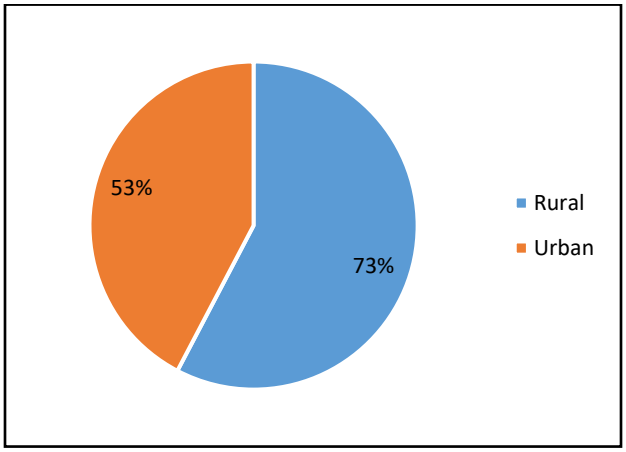
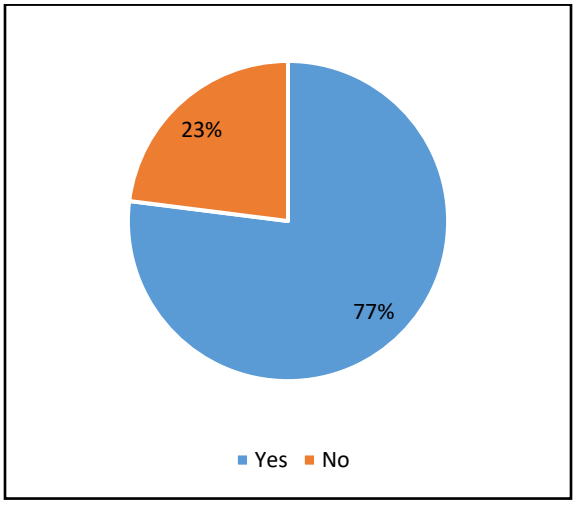


Figure 9: Teachers' level of using math and science kits by gender and school location

3.2.4. Teachers' level of Using Formative Assessment Tools

The results obtained from the classroom observation assessing the incorporation of modernized formative assessment tools in mathematics and science classrooms indicate a notable adoption rate, with 77% of teachers utilizing these tools as part of their instructional strategies. However, at 23% of teachers did not use these tools. Notably, 40% of teachers incorporated Plickers, 33% utilized voting cards, and 27% employed show me boards as part of their teaching methodologies



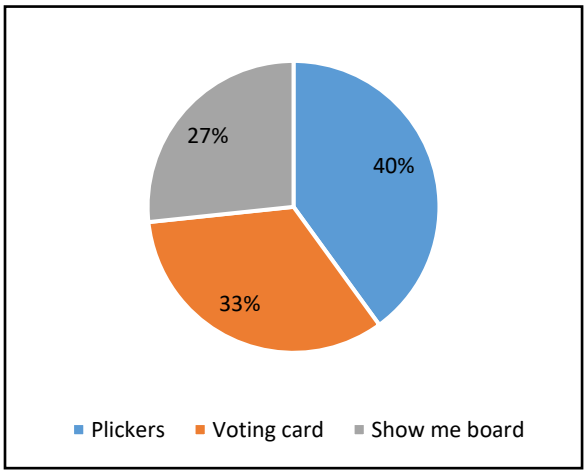


Figure 10: Mathematics and science teachers' level of using modernized formative assessment tools

Formative assessment tools used by mathematics and

Teachers' level of Using Formative Assessment Tools Based on Gender and School location,

The findings indicate that, on average, 69% of male teachers and 67% of female teachers incorporated these modern tools into their instructional practices. On the other side, according to geographical location of the school, the findings illustrated that teachers in rural area used the provided modernized tools at the percentage of 64% while in urban used these tools at the percentage of 66%

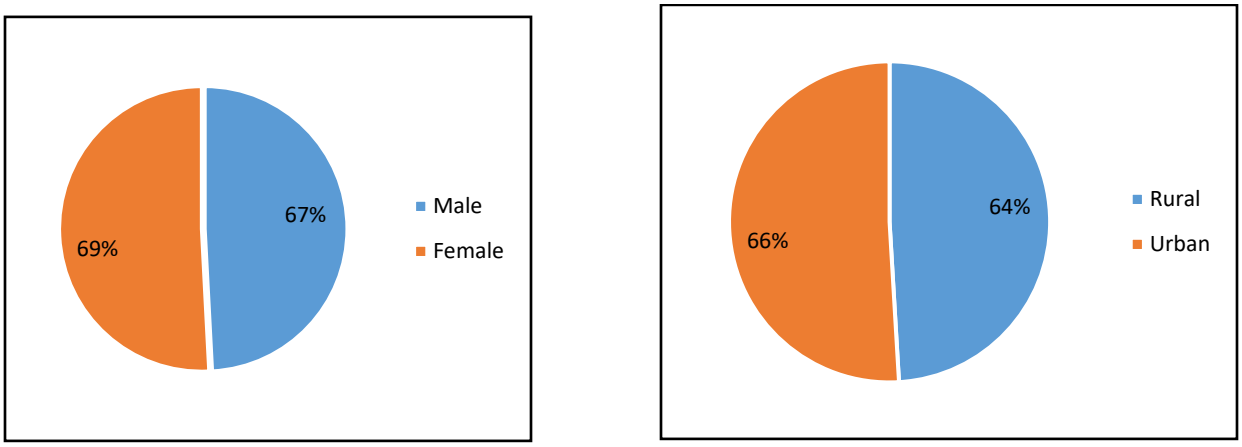


Figure 11: Teacher's level of using formative assessment tools by gender and school location

Qualitative Findings from SSLs Interview Questions

The findings from deductive thematic analysis performed by use of NVivo v.1 software, were presented according to the main themes generated from the most frequently said words that were shown the word cloud generated after importing all files of eighteen participants in the software. Participants were given codes (in form of letters) for the anonymity

Figure 12: Word cloud from SSLs responses generated from NVivo

The files were coded and generated the following main themes.

Theme 1: School Subject Leaders' (SSLs) Role in supporting their colleagues in teaching and learning Mathematics and Science

In this study, School Subject Leaders (SSLs) who participated in interview have indicated their role in supporting their colleagues in enhancing their teaching practices in science/mathematics at their schools? Some of the quotes were presented here depending on their relevance to the generated themes:

> *"I sometimes organize and participate in peer classroom observation. I use my free time or period to observation my colleagues lesson where we observe each other's teaching and provide constructive feedback. I addition we have different CPD sessions on effective methods of teaching practices in mathematics and where we share knowledge and expertise with my colleagues to improve our teaching methodology." Said teacher B*
>
> *"I support my colleagues in different CPDs sessions in every Wednesday where discussed together on the challenges of teaching mathematics and find the solution together as team." Teacher A*
>
> *As mentor, I try to collaborate with my colleagues particularly those who we teach the similar lesson (Mathematics). For example, if there is someone who have problem in teaching some concepts, I try to intervene as much as I can. Also, during the session of CPD (Continuous professional Development) that occurs on Wednesday afternoon we scientific teachers sit together and discuss on how to improve our teaching methodology. Teacher F*

Some examples of Successful mentoring experiences where SSLs witness positive changes in their colleague's teaching approach or student outcomes

when asked to highlights some examples of successful mentoring experiences one SSL said:

> *I mentored a fellow teacher who was initially hesitant to integrate technology into the classroom. Through collaborative planning and training sessions, we explored various educational apps and online resources. The colleague embraced technology, and this shift positively impacted student engagement, making lessons more interactive*
>
> *My colleagues are aware of improved lesson plan of 5Es (Engage, explore, Explain, Elaborate and Evaluate). Use of ICT is improved for both teacher and learners at our school, Nowadays, learners are*

Theme 2: School Subject Leaders' role in Ensuring Effective Use and Sustainability of Provided Materials

In their responses, School Subject Leaders who participated in this study indicated how they facilitate training sessions for teachers on the effective use of provided materials, incorporating best practices and innovative teaching methods. Some of them said that they regularly monitor the use of provided materials in classrooms through peer classroom observations, feedback, and teacher discussions.

> *"I ensure effective utilization of teaching materials by establishing clear guidelines and expectations within the department. This includes communicating the importance of proper care and usage, specifying storage protocols, and outlining responsibilities for maintaining shared resources*." Said teacher F

> *"I conduct regular CPD sessions to familiarize colleagues with new teaching materials and resources. This involves hands-on demonstrations, providing usage tips, and encouraging open discussions to address any challenges. Ongoing CPD ensures that everyone is well-equipped to utilize materials effectively."* Teacher D said

> *I regularly check in with colleagues to gauge how the materials are being used, gather feedback on their effectiveness, and address any concerns. This allows for continuous improvement and adjustments based on real-time experiences.* Teacher K

Some teachers said that in their schools the weekly reports on the use of provided materials are done by the school IT who report about the use of ICT tools like projectors and the Lab assistant report about the use of science kits

> *Teaching materials received in our school are efficiently utilized through lesson preparation, delivering lessons by using laptop and projector, in evaluation phase by using plickers and voting cards. The fact is the weekly reports from school IT and Lab assistant about the use of projectors and the related devices in teaching and learning process in most of classes where electricity is available.* said teacher J

> *I can affirm that the teaching materials received in our school are efficiently utilized. The fact is the weekly reports from laboratory assistant and the use of projector in most of classes where now electricity is available.* Teacher G

Theme 3: Challenges encountered by School Subject leaders and how they overcome them

School Subject Leaders (SSLs) expressed the challenges they face in playing this pivotal role in guiding and supporting other teachers to enhance the quality of teaching Mathematics and Science within their respective subject areas. In the discussion, we will delve into the common challenges faced by School Subject Leaders and explore strategies they employ to overcome these hurdles, ensuring effective leadership and sustained improvement in the teaching and learning process.

> *Keeping up with rapid technological advancements posed a challenge in my role.*
>
> *As a subject leader and mentor, one of the challenges I faced is managing a demanding workload and time constraints. I lack enough time for organizing meeting session because of full timetable.*

Table 1: Perceived school subject leaders' challenges and solutions used to overcome them

Challenges	**Frequency**	**Some provide solutions by SSLs to overcome the challenges**
Keeping up with rapid technological advancements	1	*To address this, I engaged in continuous professional development focused on technology integration. I also facilitated workshops for colleagues to enhance their digital literacy, fostering a culture of adaptability and innovation within the department*
Managing a demanding workload and time constraints	5	*To overcome this, I implemented effective time management strategies, prioritized tasks, and delegated responsibilities when appropriate. Additionally, I encouraged a culture of collaboration among team members to share the workload and support each other. Additionally, I encouraged a culture of collaboration among team members to share the workload and support each other.*
Dealing with diverse teaching styles among colleagues	4	*I addressed this by promoting professional development sessions that emphasized best practices and encouraged peer mentoring. This approach allowed teachers to learn from each other and adapt effective strategies to their individual teaching styles.*
Lack of electricity in some classrooms	9	For electricity no solution, we just report to the school leaders
Lack of network connection,	11	*"No sustainable solution, but sometimes I used my own internet…"* *"…taking the extra time, use of offline course, working in groups."*
Classrooms which are not appropriate for projections (walls which are not white)	3	*"…I consistently reported it to the school leaders…"* *"…I sometimes move my students to the smart room when it is not occupied"*
Overcrowded class	4	
Some teachers who are not interested in CPD	3	**"…by** *trying to approach them there is some improvement***"**

program to get new teaching approaches. There is conflict of interest		*"I try to be not discouraged in explaining the usefulness of peer learning and inviting them to observe my lesson. This gave a positive change"*

Although, the SSLs who participated in this study avowed various difficulties they are facing, most of the are committed to continuing fostering collaborative learning communities among science/mathematics teachers by creating platforms for professional exchange, collaboration, and shared learning experiences.

4. Discussion of Findings

This finding suggests a strong inclination among educators in these fields to incorporate the 5Es model into their teaching methodologies. The 5Es model, encompassing stages such as Engagement, Exploration, Explanation, Elaboration, and Evaluation, is known for its effectiveness in promoting active learning and student engagement. The high adoption rate across both subjects signifies a positive trend towards employing inquiry-based and interactive teaching methods, fostering a deeper understanding of mathematical and scientific concepts among students. The results indicate that trained math and science teachers embrace the use of 5Es model in teaching at 84%.

Interestingly, when examining the results based on gender, a subtle but noteworthy distinction emerges. Male teachers demonstrated a utilization rate of 92% for the 5Es instructional model, while their female counterparts exhibited a slightly higher rate of 94%. While the difference is minimal, it indicates a general alignment in teaching strategies between male and female educators. This consistency may stem from shared professional development opportunities, a common understanding of effective pedagogy, or institutional support for the integration of the 5Es model. The results underscore the universality of the 5Es model in mathematics and science education, transcending gender differences among teachers and reinforcing its broad acceptance as a valuable teaching framework.

Based on the school geographical location, a noteworthy distinction emerges when considering the geographical location of schools, revealing that teachers in rural areas exhibit a higher adoption rate of the 5Es model at 95%, while their urban counterparts show a slightly lower rate of 91%. This discrepancy may be influenced by various factors such as resource availability, class size, or pedagogical priorities specific to each setting.

The findings suggest that the 5Es model enjoys widespread popularity in both rural and urban educational contexts, albeit with a subtle variation, emphasizing the flexibility and effectiveness of this instructional approach across diverse teaching environments. The obtained results on the

use of 5Es highlight that there is portion of mathematics and science teachers that may require additional support, training, or resources to fully integrate that innovative pedagogy into their teaching methodologies. Overall, observations suggest that most teachers understand the importance of the Elaborate phase in promoting deeper understanding and real-world application, but there's room for improvement in providing further explanations and utilizing scenarios uniformly. The obtained results align with the Bahtaji (2021) who highlight that the use of 5Es increase students engagement in a lesson. In addition, Ahmad et al. (2018) showed that all phases of 5Es provide ample space for students' hands-on practices of the learning contents.

The observed prevalence of technology integration, as indicated by the 81% usage rate, aligns with the broader trend in contemporary education towards leveraging modernized tools for more effective and interactive instruction. The results imply a positive momentum towards modernizing teaching practices in mathematics and science. Nonetheless, attention should be given to the 19% who have not yet incorporated projectors and computers into their teaching, as addressing potential barriers or providing targeted professional development could further enhance the overall technological integration among educators. This insight underscores the importance of ongoing support and professional development initiatives to ensure that all teachers can harness the benefits of modern tools for the benefit of student learning and engagement in mathematics and science classrooms.

The findings underscore the evolving landscape of formative assessment practices in mathematics and science education, emphasizing the need for ongoing support and professional development to ensure all educators can effectively integrate these tools into their teaching methodologies, ultimately enhancing the learning experience for students. These results highlight the diverse strategies educators employ to measure student understanding and facilitate real-time feedback. The prevalence of Plickers, voting cards, and show me boards indicates a recognition of the value of interactive and technology-enhanced assessment tools in the teaching of mathematics and science. However, the variations in usage percentages suggest that teachers may choose tools based on individual preferences, classroom dynamics, or available resources. This insight underscores the importance of acknowledging and supporting the diverse array of formative assessment tools that cater to the unique needs and preferences of educators in mathematics and science classrooms. In was supported by Nkundabakura et al. (2023) illustrated used of modern tools and innovative teaching and learning methods to improve the educational process.

These findings underscore the importance of ongoing professional development opportunities to enhance teachers' skills and comfort levels with the utilization of scripted lessons and mathematics and science kits. Although more than a half of teachers 59% have indicated a good level of utilizing scripted lesson but there is still a journey to support 41% teachers who indicated that they have difficulties in using scripted lessons. Ensuring that all educators have the necessary training and support is crucial for maximizing the benefits of interactive learning, hands-on and experiential learning approaches facilitated by these mathematics and science kits and the resources embedded in scripted lessons like animations and simulations. This was in agreement with Larsen (2018) who

explained that the use of science kits motivate learners and increases students' engagement in the lesson.

5. Conclusions

The findings of this study shed light on the positive impact of trainings and instructional tools provided by Rwanda Quality Basic Education for Human Capital Development (RQBEHCD) Project, Sub-Component 1.2. As the findings indicate, a good percentage of trained teachers are effectively utilizing the materials they have received like computer and projectors, science kits and formative assessment tools. In addition, the findings indicated that a considerable percentage of teachers are proficient in preparing and delivering 5Es based lessons in their respective subjects. This is indeed a commendable stride towards enhancing the quality of mathematics and science education. However, the study also highlights areas that demand attention and improvement, particularly in the use of scripted lessons where the usage percentage is at 59% and science kits where the usage percentage is at 60%. As far as the continuous professional support to math and science teachers by the project, sub-component 1.2 is concerned, the study recommends to reinforce the CPD program within the schools through empowering and equipping the school subjects' leaders with necessary skills to support their peer teachers.

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Article 7

The Implementation and Impact of The Montessori STEM Curriculum for Girls in Northern Nigeria : A Case Study of Zaria and Sabon Gari Local Government Area, Kaduna State

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Abstract

The Montessori curriculum in STEM (Science, Technology, Engineering, and Mathematics) offers a transformative educational approach tailored to the unique challenges and opportunities faced by girls in northern Nigeria. This curriculum emphasizes hands-on, experiential learning and student-centred discovery, fostering an environment where girls can develop critical thinking, creativity, and problem-solving skills. By integrating interdisciplinary learning, the Montessori STEM approach allows students to see the connections between scientific concepts and their real-world applications, thereby making learning more relevant and engaging.In the context of northern Nigeria, where educational access and gender disparities pose significant challenges, the Montessori STEM curriculum provides an inclusive and empowering framework. It creates a prepared environment where girls are encouraged to explore, experiment, and engage with STEM subjects freely. This approach is particularly impactful in challenging stereotypes and breaking down barriers that often prevent girls from pursuing STEM careers. The Montessori method's emphasis on practical life skills, sensorial experiences, and project-based learning equips girls with the tools and confidence to succeed in STEM fields. Teachers act as facilitators, guiding students through their individual learning journeys and fostering a supportive community that values each student's unique contributions. Research indicates that Montessori education can significantly enhance academic achievement, creativity, and self-efficacy in STEM among girls, particularly in underrepresented and underserved regions. This abstract explores the implementation and impact of the Montessori STEM curriculum for girls in northern Nigeria, highlighting its potential to drive

educational equity, economic development, and social progress by nurturing the next generation of female innovators and leaders.

1. Introduction

Education is a powerful tool for social change, and early childhood education plays a crucial role in shaping a child's future. In Northern Nigeria, where gender disparities in education are pronounced, particularly in STEM (Science, Technology, Engineering, and Mathematics) fields, there is an urgent need to explore innovative approaches to bridge this gap. The Montessori method, known for its child-centred approach and emphasis on hands-on learning, offers a promising framework for introducing STEM education at the preschool level. This paper investigates the implementation and impact of the Montessori STEM curriculum for preschool girls in Northern Nigeria, focusing on its potential to empower young girls and promote gender equity in education.

2. Background

Gender Disparities in STEM Education

Globally, women are underrepresented in STEM fields, and this trend is even more pronounced in developing countries like Nigeria. In Northern Nigeria, cultural norms, poverty, and inadequate educational infrastructure contribute to the low enrollment and retention of girls in schools, particularly in STEM subjects. Early exposure to STEM concepts is critical in fostering interest and competence in these fields, making preschool education a key area of intervention.

The Montessori Method

The Montessori method, developed by Dr. Maria Montessori in the early 20th century, is based on the principles of self-directed learning, hands-on activities, and collaborative play. The method emphasizes the importance of creating a prepared environment where children can explore and learn at their own pace. Montessori education is known for its effectiveness in fostering cognitive, social, and emotional development, making it a suitable approach for early childhood education.

STEM Education in Montessori

STEM education in the Montessori context involves integrating science, technology, engineering, and mathematics into the curriculum through hands-on activities and real-world applications. This approach encourages children to develop critical thinking, problem-solving, and collaboration skills from an early age. By incorporating STEM into the Montessori curriculum, educators can provide young girls with the foundation they need to pursue STEM fields later in life.

2.1 Implementation of the Montessori STEM Curriculum in Northern Nigeria

Contextual Considerations

Implementing the Montessori STEM curriculum in Northern Nigeria requires careful consideration of the local context. The region is characterized by diverse cultural practices, religious beliefs, and socio-economic challenges that influence educational practices. Therefore, successful implementation must be culturally sensitive and aligned with the values and expectations of the community.

Teacher Training and Development

One of the key components of successful implementation is the training and development of teachers. Montessori educators need to be well-versed in both the Montessori method and STEM education to effectively deliver the curriculum. In Northern Nigeria, where teacher training programs are often limited, it is essential to provide specialized training that equips teachers with the skills and knowledge needed to implement the Montessori STEM curriculum.

Curriculum Design and Delivery

The Montessori STEM curriculum should be designed to be flexible and adaptable to the local context. This includes incorporating locally relevant STEM activities and materials that resonate with the experiences and interests of preschool girls in Northern Nigeria. For example, using local materials for hands-on activities can make STEM concepts more relatable and accessible.

2.2 Impact of the Montessori STEM Curriculum on Preschool Girls

Cognitive Development

Research has shown that early exposure to STEM education can significantly enhance cognitive development in young children. The Montessori method, with its emphasis on hands-on learning and exploration, provides an ideal environment for fostering cognitive skills such as critical thinking, problem-solving, and logical reasoning. For preschool girls in Northern Nigeria, the Montessori STEM curriculum has the potential to lay a strong foundation for future academic success in STEM subjects.

Social and Emotional Development

In addition to cognitive development, the Montessori STEM curriculum also promotes social and emotional development. Collaborative activities in the Montessori classroom encourage girls to work together, share ideas, and develop communication skills. This collaborative approach can help build confidence and self-esteem, which are crucial for overcoming gender stereotypes and pursuing careers in STEM fields.

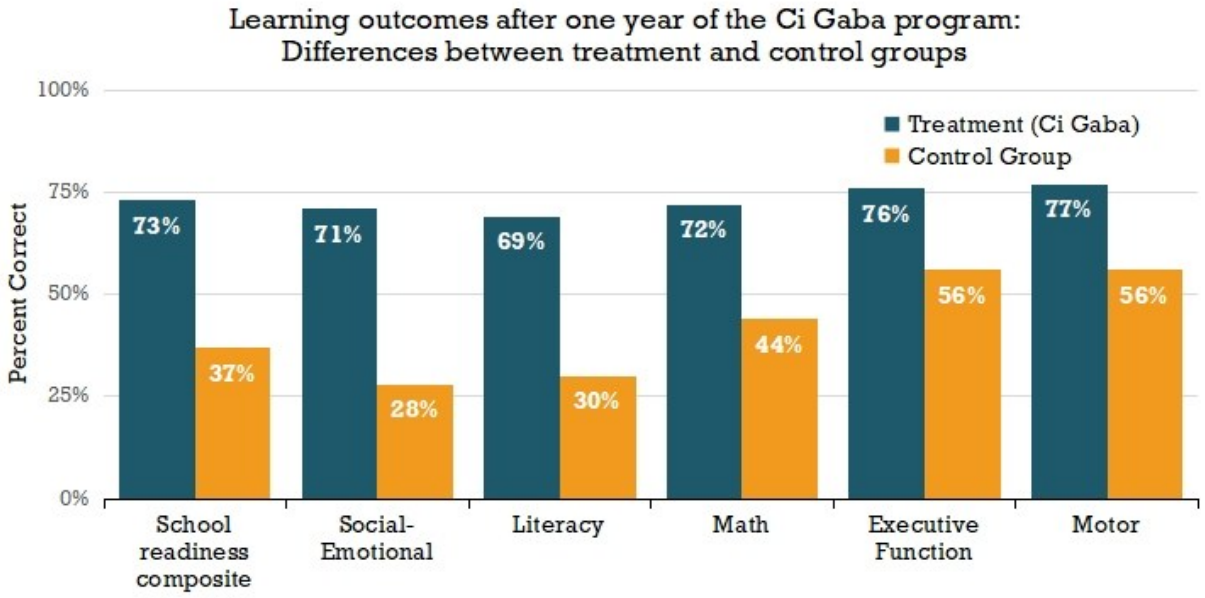
Gender Equity and Empowerment

The implementation of the Montessori STEM curriculum for preschool girls in Northern Nigeria can play a significant role in promoting gender equity and empowerment. By providing girls with early exposure to STEM education, the curriculum challenges traditional gender roles and encourages girls to envision themselves as future scientists, engineers, and mathematicians. This early intervention is critical in addressing the gender gap in STEM fields and empowering girls to pursue their interests and aspirations.

These are evident with the research carried out in 16 communities for 480 girls in Zaria and Sabon gari Local Governments categorized into 8 control and 8 intervention communities that were randomly selected, the tool used for the assessment is the International Development and early learning Assessment (IDELA)

3. Results and Findings

After one year, girls from intervention, communities assigned to the program had higher scores on all measured learning outcomes compared to girls from communities who were not assigned to the program. The contrast between the girls assigned to the preschool program and girls assigned to the control is stark. Girls in communities assigned to the Ci Gaba program accurately responded to an average of 73% of assessment items, whereas girls in the control group accurately responded to an average of 37%. These effects persisted across all areas of school readiness.



School readiness is a comprehensive measure that captures a child's preparation cognitively, socially, and emotionally for success in primary school and for later learning and life. Social-emotional skills represent children's ability to do such things as play with other children, share materials, and have empathy for others. Executive functioning includes staying focused on tasks, self-control, and other skills that underlie the capacity to plan ahead. Fine motor skills are commonly seen in activities like using pencils, buttoning and unbuttoning, and cutting out simple shapes with safety scissors.

In addition, evaluation team conducted twice monthly structured observations of preschool classes. Six months into the program, most girls hardly concentrate and focus on activities carried out in the safe space and do very basic addition and subtraction. The structured observations also found that motor control and coordination, increased independence, concentration, and a sense of responsibility are being acquired. For example, most of the girls have mastered the tripod pencil grip (holding a pencil with the thumb, index, and middle fingers).

Dr. Wolf, a renowned professor in human development and quantitative methods at the university of Pennsylvania graduate school of education together with the team conducted the analysis of the raw data and is working with the team to track the participants into primary school to see if these large initial effects persist. Data from earlier cohorts are extremely encouraging. Girls who attended the preschools have done better on their primary school oral entrance exams and were more likely to gain entrance than the girls not in the program. Interviews with the first cohort's primary school teachers suggest that the girls were emotionally, socially, and academically ready for school enrolment; 90% of the girls are performing at the top of their class and are taking up leadership roles in their various classes.

3.1 Challenges and Barriers to Implementation

Cultural and Societal Norms

One of the main challenges to implementing the Montessori STEM curriculum in Northern Nigeria is overcoming cultural and societal norms that limit girls' access to education. In some communities, there is resistance to educating girls, particularly in subjects like STEM, which are traditionally viewed as male-dominated fields. To address this challenge, it is essential to engage with community leaders and parents to raise awareness about the importance of girls' education and the benefits of STEM education.

Infrastructure and Resources

Another significant challenge is the lack of infrastructure and resources in many parts of Northern Nigeria. Schools may lack the necessary facilities, materials, and equipment to effectively implement the Montessori STEM curriculum. Additionally, there may be a shortage of trained teachers who can deliver the curriculum. Addressing these challenges requires investment in educational infrastructure, teacher training, and the provision of necessary resources.

Sustainability and Scalability

Ensuring the sustainability and scalability of the Montessori STEM curriculum is another critical consideration. Pilot programs may demonstrate success, but scaling up these initiatives across the region requires sustained funding, ongoing support, and a commitment to long-term outcomes. Partnerships with government agencies, non-governmental organizations, and the private sector can play a vital role in supporting the expansion and sustainability of the Montessori STEM curriculum in Northern Nigeria.

4. Recommendations for Successful Implementation

Community Engagement and Advocacy

Engaging with the community is essential for the successful implementation of the Montessori STEM curriculum. This includes involving parents, community leaders, and local organizations in the planning and implementation process. Advocacy efforts should focus on raising awareness

about the importance of girls' education and the benefits of STEM education for both individuals and the broader community.

Investment in Teacher Training

Investing in teacher training is critical to the success of the Montessori STEM curriculum. Teachers need to be equipped with the knowledge and skills to deliver the curriculum effectively. This includes training in the Montessori method, as well as specialized training in STEM education. Ongoing professional development opportunities should also be provided to ensure that teachers stay up-to-date with the latest educational practices.

Development of Culturally Relevant Curriculum

The curriculum should be designed to be culturally relevant and adaptable to the local context. This includes incorporating local materials, examples, and activities that resonate with the experiences of preschool girls in Northern Nigeria. By making the curriculum relatable and accessible, educators can enhance the effectiveness of STEM education and increase its impact on girls' learning outcomes.

Monitoring and Evaluation

Regular monitoring and evaluation are essential to assess the impact of the Montessori STEM curriculum and identify areas for improvement. This includes tracking student progress, evaluating teacher performance, and gathering feedback from parents and community members. Data collected through monitoring and evaluation can inform future program adjustments and ensure that the curriculum continues to meet the needs of preschool girls in Northern Nigeria.

5. Conclusion

The implementation of the Montessori STEM curriculum for preschool girls in Northern Nigeria holds significant potential for promoting gender equity and empowering young girls to pursue careers in STEM fields. While challenges such as cultural norms, infrastructure limitations, and resource constraints exist, these can be addressed through community engagement, teacher training, and the development of a culturally relevant curriculum. By providing early exposure to STEM education, the Montessori method can help bridge the gender gap in STEM and contribute to the overall development and empowerment of girls in Northern Nigeria. Continued investment, advocacy, and support are necessary to ensure the long-term success and sustainability of this initiative.

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Article 8

Digital Literacy of Senior School Chemistry Teachers in Nigeria: Challenges and Prospects

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Abstract

Before now, digital literacy only encompassed acquiring digital skills on the use of the self-supporting computers. However, the advent of the internet and use of social media has resulted in the shift in some of its focus to mobile devices. Thus, everyone is increasingly pressured to acquire skills that can help navigate a demanding complex digital world safely. This paper employs secondary sources of data from reports, journals and findings of other researchers on the overview of concept of digital literacy and its benefit such as flexible nature, gives room for collaboration, solves problem of voluminous syllabus, and solves problem of hazardous practicals in chemistry. The paper also outlines some constraints of digital literacy as; poor teachers' TPACK, poor funding, Poor Power Supply in the Country, poor maintenance and insecurity. The study recommends that efforts should be made by government to expose science teachers to pre-service, in-service trainings in form of seminars and workshops, adequate funding to procure digital gadgets, regular power supply, good maintenance culture and security of the digital gadgets.

Keywords: *Chemistry education, Digital literacy, ICT, Senior school teachers*

1. Introduction

The surge in population, knowledge explosion, and the growing pervasiveness of Information and Communication Technology (ICT) globally, necessitated the need to expand, promote and improve the quality of teaching and learning of science and technology. This obvious advancement in the field of ICT has greatly influenced teaching and learning processes in our institutions, the senior schools not exempted. With this development, education systems around the world are increasingly pressured to integrate ICT into teaching and learning for their citizens to acquire the required 21st century skills. Thus, presenting a new challenge to education sector. In view of this, the issue of ICT policy became an official statement in Nigeria through formulation of a National Information Technology Policy (NITP) by the Federal Executive council. This also led to establishment of implementing agency called the National Information Technology Development Agency (NITDA). The agency was charged with the responsibility of implementing Nigeria's IT

policy (Oso, 2018). The Federal Government of Nigeria also commissioned a Mobile Internet Unit (MIU) to effectively equip secondary schools with ICT tools and the unit was operated by NITDA.

Consequently, every job and career are increasingly impacted by technology, the need to build digitally literate Nigeria and to meet 95% digital literacy levels across states and local governments by 2030 (Federal Ministry of Communications and Digital Economy & National Information Technology Development Agency 2023). Thus, ICT integration becomes imperative. Also, the advocacy for a shift from teacher-centered learning approaches to student-centered approaches can be achieved if backed up with integration of the innovative and technological advancement offered by digital learning. Ikemelu (2015) canvassed that application of ICT in teaching of science and technology subjects is one of the indispensable tools for achieving an effective classroom curriculum delivery because it enhances conceptual understanding and promotes higher order thinking skills. Hence, ICT application in teaching and learning creates excitement and stimulates critical thinking for conceptual understanding of scientific concepts. With this, teachers' knowledge of technology, otherwise digital literacy cannot be undermined. Teachers not only have to become familiar with ICT, but also acquire pedagogical expertise needed to fruitfully work with the new technology-based learning environment (Dhingra & Rahman, 2014). The need for teachers to be digitally literate becomes imperative.

2. The Concept of Digital Literacy and Its Relevance to Chemistry Teaching

Digital literacy is the ability to live, learn, and work in a society where communication and access to information is increasing through digital technologies such as internets, social media platforms and mobile devices (Western Sydney University, 2020). Hence, digital literacy could mean the potentiality of individuals and communities to understand and use digital technologies for meaningful actions within life situations (Kumari & D'Souza, 2016). The essential components of digital skills are communicating, handling information and content, problem solving and staying safe and legal online. Acquiring these essential skills enhances the knowledge required for content creation, critical thinking and social engagement with others in cyberspace. As such, individual with digital literacy skills must be able to use technology as the digital age's information management tools (Kaeophanuek et al., 2018).

Before now, digital literacy only encompassed acquiring digital skills on the use of the self-supporting computers. However, the advent of the internet and use of social media has resulted in the shift in some of its focus to mobile devices. A few examples of basic digital literacy skills include using phones to check emails, creating an online profile on social media platforms, using an online search engine to proffer solutions to problems and evaluating the credibility of online resources before usage.

With the world becoming more automated, everyone is increasingly pressured to acquire skills that can help navigate a demanding complex digital world safely. Today, smart phone users worldwide surpass six billion and is forecast to further grow by several hundred million in the next few years. Although, digital literacy does not replace traditional form of literacy, it however builds upon and expands the skills that form the foundation of the traditional forms of literacy. Ultimately, digital literacy shares many defining principles with other fields and more specifically, education. As such, four specific models of text-participating; code-breaking, text-analyzing, and text using are recommended while engaging with digital media (Furber, 2012).

Generally, digital literacy gives educators chance to combine their pedagogical content knowledge (PCK) with technology and thus, help their students become more familiar with digital tools. When teachers demonstrate digital literacy skills such as use of blog posts, podcasts and networking in the classroom, it provides a modern approach to engaging students in the classroom curriculum. Students can be guided towards creating content such as presentations, videos and thus, improving their academic achievement. Also, digital literacy creates more opportunities for collaboration. Students can create and edit presentations simultaneously on different computers, share and edit notes through cloud-based software, discuss classroom topics through group messaging apps and reply to one another's discussion on educational forums.

Also, educational objectives of applying, analyzing, evaluating and creating, classified as higher order thinking skills in the revised Bloom's taxonomy can be easily achieved by the teachers (Kumari & D'Souza, 2016). Digital literacy helps the teacher to think beyond Google for information access and thus, pushing students to higher levels of creativity. Digital citizenship is also promoted in students as a digitally literate teacher emphasizes the effects of plagiarism and cyberbullying and this in turn allows the students to think originally and creatively in their academics.

More specifically, digital literacy indicators in chemistry include information literacy, digital communication, content creation, safety and problem solving (Nada & Saaari, 2020). The information literacy encompasses the ability to search, locate, assess, read, and critically evaluate the accuracy and credibility of chemical information found on the internet through the digital devices; digital communication are skills required to discuss, share, collaborate online in group for digital building of chemical resources and content; content creation focused on acquiring skills on how to create, develop chemical content, understand the copyright and license of digital works, and modify software applications.

Also, digital literacy emphasizes reading, writing understanding, evaluating, communicating and using information in different format (Dewi et al., 2021). Hence, the difficulty of inability to effectively teach and learn chemistry encounter by teachers and students can be eradicated. Researchers such as Adesoji et al. (2017) and Cardellini (2012) have established that chemistry is a difficult and complex subject because of inability of students to effectively grasp chemistry concepts. With the help of digital skills and unlocking technology for instruction make it easy to

utilize technological tools to create content for remote learning. Thus, chemistry teachers' digital literacy skills could help chemistry students to overcome problem of inability to grasp chemistry concepts collaboration and students- to students' interactions since learners can interact with peers through e-mail or chat without any time constraints. Therefore, the problem of abstract nature of chemistry as claimed by Samba and Eriba (2012) could be solved.

The creation of e-folios that combine text, images, presentations, video, audio, links and a discussion space to demonstrate mastery of a specific content area or subject matter is possible with digital literacy. E-folios could solve problem of voluminous syllabus as stated by Njoku and Nzewi (2015) to be one of the problems militating against teaching and learning of chemistry in Nigeria. E-folios help to facilitate the exchange of ideas, discourse and subject area feedback between students and teacher, thus, creating meaningful learning experience for students. Students' e-folios could also be enriched by computer-assisted simulations to demonstrate practical to appear near reality in the absence of necessary laboratory equipment. It could also be used to demonstrate some concepts in chemistry practicals that can become hazardous to health such as evolution nitrogen dioxide and fluorine gases.

Digital literacy gives room for learning asynchronously. Asynchronous learning according to Oluwaniyi et al. (2015) removes problem of overcrowding and distractions as learning becomes ineffective when there is overcrowding in classrooms resulting in unnecessary noise, inconveniences and lack of concentration. Therefore, conducive environment which could be decided by the learners themselves and thus, alleviate problem of confusion in learning chemistry. Raymond et al. (2016) asserted that anytime-anywhere nature of asynchronous learning allows learners to have access to instructional materials from the teacher for learning from any location with an internet location. This allows for accessibility for diverse students' populations. Thus, providing learners with opportunity to learn anytime, anywhere without the physical presence of the teacher through recorded lectures, power point slides and reading assignments.

This benefit eliminates the fear of school authority in giving opportunities to any chemistry teacher that may want to be on programs for upgrading of academic qualification or in-service professional development in his or her field. Oluwaniyi et al. (2015) also buttressed that the use of clear headings, visuals, screen friendly fonts and colors makes students learn better. Hence, the use of color and visuals to depict some concepts in chemistry such as separation techniques, identification of gasses, nitrogen cycles, saponification to name a few could motivate students to learn. Also, a surprisingly difficult digital literacy task in chemistry is searching for information on particular chemical compounds or reactions (Mantha, 2023). Tools like chemspider, labXchange platform make finding chemical information much easier for teachers, students and researchers.

3. Challenges of Digital Literacy in Teaching and Learning in Nigeria

With the emergence of social media such as Facebook, Twitter, Instagram, and so on, people can communicate and connect with one another in a new and different ways. Digital literacy has to do with the use of digital gadgets on these social media platforms. As such, there are many problems militating against acquiring digital literacy skills for effective classroom delivery. Some of these challenges include:

Poor Teachers' Technological Pedagogical Content Knowledge (TPACK):

Currently, technology is considered a separate knowledge from the knowledge of teaching and learning. Several professional development workshops have been organized where teachers are instructed on how to effectively utilize some particular software or applications. However, how to properly integrate them into our classroom are yet to be discussed. Although, TPACK is not designed to be an entire package, its framework allows technology to be integrated into the content and pedagogy in our classrooms and this could help the students learn more effectively and ensures digital safety.

Digital safety is the ability to protect personal data, personal health, owned digital devices and the environment from digital world while, problem solving skills encompass the ability to solve technical problems with digital technologies, identify the needs and responses of technology in learning and identify the digital competency gaps. Hence, presenting new challenge to the teachers and other stakeholders. That is, with TPACK, the teacher should be able to use search engines optimally; teaches learners to be ideal digital citizens, minimizes the digital divide, chooses correct applications or tools for teaching, improves technology and ultimately, upgrades teaching standard.

Poor Funding:

Inadequate funding for the purchase of digital gadgets due to insufficient budgetary allocation to education sector has been a challenge to effective e-learning in Nigerian senior schools. ICT gadgets are very expensive thus; their purchase becomes an uphill venture when there is no money. Akani (2016) reported that since 1960 Nigeria has never allocated one-third of the United Nations benchmark of 26 percent for developing countries of the annual budget to education.

Power Supply in the Country:

Digital gadgets require electricity supply to function. However, lack of regular and adequate power supply in Nigeria imposes constraint to utilization of these services.

Lack of maintenance Culture:

The challenge of lack of trained and experienced personnel to maintain available gadgets has been a problem in integrating e-learning into the teaching and learning of chemistry. Despite the stipulation in the 2013edition of the National Policy on Education that ICT should be integrated into teacher education at all levels, the poor maintenance practices has remained a challenge.

Insecurity:

Vandalization of digital gadgets by thieves is a threat, abject poverty and unemployment of larger part of nation's population have contributed to a high rate of insecurity of installed digital gadgets. Akani (2016) submitted that some school administrators and people who can afford the purchase of these gadgets are afraid of them being stolen.

4. Proffered Solutions to the Challenges of Digital Literacy and Recommendations

1. A strategic plan to equip all schools with good infrastructural facilities for successful technology integration should be developed and monitored for full implementation; and TPACK curriculum should be designed and implemented for both pre-service and in-service teachers' programmes.
2. The Federal and State Governments as well as all other stake holders in Nigerian senior schools should ensure adequate funding so that the purchase of digital tools and other things that are involved in the installation services of these gadgets will not be difficult.
3. Regular supply of electricity is very crucial in facilitating e-learning. Electricity is the heart of every technology. Therefore, the government should give attention to power generation in order to have country with uninterrupted power supply in the rural and urban areas. The government should also while providing electricity to ensure link up with telecommunication facilities for actualization of e-learning.
4. Technical support staff for the maintenance of digital facilities is imperative. Government and other stake holders should assist the school administrator in recruiting trained and experienced maintenance personnel to manage control and maintain the digital gadgets for efficiency and effectiveness.
5. Adequate security should be provided by the government and communities in order to safe-guard the gadgets from being stolen and vandalized by thieves.

5. Conclusion

The enumerated challenges are fundamental problems that could impede students and teachers to embrace digital literacy, peculiar to developing countries such as Nigeria. However, if the proffered solutions are adopted, teachers' digital literacy reduces the constraints of the conventional methods of teaching. It saves time and resources since teachers can deliver their lessons anytime, anywhere and can monitor the activities and performances of their students to acquire knowledge without being physically present. Digital literacy, without hesitation is a solution to the challenges of conventional methods of teaching chemistry.

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Article 9

Innovative Pedagogy and Emerging Technologies in STEM Learning: Strategies, Platforms, And Educational Tools

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Abstract

As education evolves, the integration of innovative pedagogical strategies and emerging technologies is transforming STEM learning. This paper examines how personalized learning platforms, along with the incorporation of robotics and coding are enhancing STEM education for both basic and post-basic learners.

1. Introduction

In the modern educational landscape, innovative teaching methods and technological tools are crucial for effective STEM education. This paper explores the role of personalized education and emerging technologies, such as robotics and coding, in shaping the future of STEM learning. As educators strive to improve student outcomes, they are increasingly adopting strategies that foster engagement, critical thinking, and problem-solving skills. This study aims to provide a comprehensive overview of the current state of innovative pedagogy and technology in STEM education, highlighting best practices and emerging issues.

1.1 Contextual Background

STEM (Science, Technology, Engineering, and Mathematics) education has undergone significant transformation in recent years. As the global economy increasingly relies on technological innovation and scientific advancement, the need for effective STEM education has never been more critical. In Africa, the shift towards a knowledge-based economy highlights the necessity for educational reforms that address the evolving demands of the workforce and society (Alao, 2020; Osuafor, 2021).

One of the most promising developments in STEM education is the integration of innovative pedagogical strategies and emerging technologies. These advancements are reshaping traditional teaching methods, making learning more interactive, personalized, and engaging. For instance, personalized learning platforms, which tailor educational content to the individual needs of each student, have been shown to improve learning outcomes by accommodating diverse learning styles

and paces (Okpala, 2022). Similarly, the incorporation of robotics and coding into the curriculum is fostering critical thinking, problem-solving, and technical skills that are essential for the 21st-century workforce (Ali, 2019; Nwosu, 2023).

The importance of these innovations cannot be overstated. As Africa continues to develop its educational infrastructure, leveraging such technologies can help bridge the gap between traditional education systems and the needs of a modern, tech-driven world. In particular, the rise of robotics and coding in educational settings is providing students with hands-on experiences that enhance their understanding of complex concepts and prepare them for future careers in STEM fields (Adebayo & Oladipo, 2021).

1.2 Purpose of the Study

This study aims to explore the impact of personalized learning platforms and tools such as robotics and coding on STEM education. The focus is on understanding how these innovative approaches can enhance student engagement and learning outcomes. By examining the role of these technologies, the research seeks to provide insights into their effectiveness and the challenges associated with their implementation.

1.3 Research Questions

1. **How do innovative teaching methods impact student engagement and learning outcomes in STEM?**
    - This question seeks to investigate the effectiveness of modern pedagogical strategies, such as personalized learning platforms and interactive technologies, in fostering a more engaging and productive learning environment.
2. **What role do robotics and coding play in developing critical skills in STEM students?**
    - Here, the aim is to assess how the integration of robotics and coding into the STEM curriculum contributes to the development of essential skills such as problem-solving, creativity, and technical proficiency.
3. **What challenges arise with the implementation of personalized STEM learning platforms?**
    - This question focuses on identifying the barriers and difficulties encountered in deploying personalized learning tools, including technological, pedagogical, and infrastructural issues.

2. Literature Review

2.1 Innovative Pedagogical Strategies in STEM Education

Innovative pedagogical strategies are pivotal in advancing STEM education. Among these strategies, project-based learning (PBL), flipped classrooms, and inquiry-based learning (IBL) have garnered significant attention for their potential to enhance student engagement and learning outcomes.

Project-Based Learning (PBL) involves students working on complex, real-world projects that require critical thinking, collaboration, and creativity. This approach has been shown to foster deeper understanding and retention of STEM concepts. For instance, a study by Afolabi (2021) demonstrated that PBL in Nigerian secondary schools improved students' problem-solving skills and increased their interest in STEM subjects. By engaging students in authentic tasks, PBL encourages active learning and helps students connect theoretical knowledge with practical applications (Akinmoladun, 2022).

Flipped Classrooms shift traditional instructional methods by having students first engage with new material at home through videos or readings, and then apply this knowledge in class through problem-solving activities. This method has been effective in increasing student participation and performance. In an African context, Ojo and Ojo (2020) reported that implementing flipped classrooms in Nigerian universities led to enhanced student engagement and improved academic achievement in STEM courses. This approach allows for more interactive and collaborative learning experiences during class time (Oladipo & Akinlade, 2023).

Inquiry-Based Learning (IBL) emphasizes student-driven investigations where learners pose questions, conduct experiments, and analyze results. This strategy promotes critical thinking and fosters a deeper understanding of STEM concepts. Research by Adeoye and Adeyemi (2022) highlights that IBL methodologies in African schools have positively impacted students' analytical skills and interest in scientific inquiry. By focusing on exploration and discovery, IBL encourages students to develop a scientific mindset and problem-solving abilities (Ogunyemi & Dada, 2021).

2.2 STEM Learning Platforms and Personalized Education

Learning platforms such as Khan Academy, Edmodo, and Coursera have revolutionized the delivery of STEM education by offering personalized learning experiences. These platforms provide tailored educational content and resources that cater to individual learning needs and preferences.

Khan Academy offers a vast array of educational videos, exercises, and assessments that allow students to learn at their own pace. Studies have shown that Khan Academy's adaptive learning features help students improve their math and science skills by providing personalized feedback and targeted practice (Adewale, 2022). This personalized approach has been particularly beneficial

in Nigeria, where traditional classroom settings often face challenges in addressing diverse learning needs (Onyeama & Afolabi, 2021).

Edmodo serves as a collaborative learning environment where students and teachers can interact, share resources, and track progress. Research by Ifeoma and Okechukwu (2023) indicates that Edmodo's features, such as customizable assignments and real-time feedback, support differentiated instruction and enhance student engagement in STEM subjects. However, challenges such as limited access to reliable internet and technological infrastructure can hinder the effective use of such platforms in some African regions (Chukwu & Alabi, 2021).

Coursera provides online courses from global institutions, offering students access to high-quality STEM education resources. The platform's ability to deliver content from top universities can bridge educational gaps and provide advanced learning opportunities. A study by Oladipo and Olalekan (2023) found that Coursera's courses have improved students' understanding of complex STEM topics and facilitated skill development, although issues related to internet access and course completion rates persist in certain areas (Moses & Adesina, 2022).

2.3 Emerging Technologies: Robotics and Coding Education

The integration of robotics and coding into education is transforming STEM learning by providing students with hands-on experiences that enhance their problem-solving and technical skills.

Robotics Education introduces students to engineering principles and programming through building and controlling robots. This practical approach helps students apply theoretical knowledge in a tangible way. Research by Adebayo and Akinleye (2021) indicates that robotics education in Nigerian schools has significantly improved students' interest in STEM fields and their ability to work collaboratively on technical projects. Robotics kits and competitions have become popular tools for fostering engagement and learning in STEM subjects (Eze & Chukwu, 2023).

Coding Education equips students with essential programming skills that are increasingly valuable in the digital age. Coding activities develop logical thinking, creativity, and problem-solving abilities. A study by Olusegun and Oluwaseun (2022) found that incorporating coding into the curriculum has positively impacted students' performance in STEM subjects and prepared them for future technological careers. Coding initiatives, such as the use of platforms like Scratch and Python, have shown promise in enhancing students' technical competencies and interest in technology-related fields (Akinloye & Adetola, 2023).

Case Studies further illustrate the effectiveness of these technologies. For example, a project implemented in Kenya introduced robotics and coding to secondary school students, resulting in improved academic performance and increased enthusiasm for STEM careers (Mugisha & Tindimwebwa, 2023). Similarly, in Nigeria, coding bootcamps and robotics workshops have demonstrated success in engaging students and fostering a deeper understanding of STEM concepts (Okonkwo & Ibe, 2024).

In summary, innovative pedagogical strategies and emerging technologies are playing a crucial role in enhancing STEM education in Africa. While the benefits are clear, addressing the associated challenges is essential for maximizing the impact of these advancements on student learning and development.

3. Methodology

3.1 Study Design

This study employs a comprehensive review method to analyze current pedagogical practices and technological tools in STEM education. The review aims to synthesize existing literature and evaluate the effectiveness of innovative pedagogical strategies, persoSTEM Education in Underserved Communities: Examining the challenges and solutions for delivering high-quality STEM education in underserved and rural communities.nalized learning platforms, and emerging technologies such as robotics and coding.

Selection Criteria**:** Studies and case examples were selected based on their relevance to the research questions, quality of evidence, and applicability to both Nigerian and international contexts. Criteria for inclusion included:

1. **Relevance:** The study must address the impact of pedagogical strategies or technological tools on STEM education.
2. **Quality:** Preference was given to peer-reviewed articles, reputable educational reports, and high-quality technology reviews.
3. **Applicability:** Studies that provided insights into diverse educational settings, including those from Nigeria and other regions, were prioritized to offer a comprehensive understanding of the global and local context.

Studies were also selected to cover a range of educational levels, from basic to post-basic education, ensuring that the review captures a broad perspective on the integration of these strategies and tools.

3.2 Data Collection

Data was collected from a variety of sources to ensure a thorough review of the literature:

Scholarly Articles: Peer-reviewed journals were accessed through academic databases such as Google Scholar, JSTOR, and PubMed. Keywords used included "STEM education," "innovative pedagogical strategies," "personalized learning platforms," "robotics education," and "coding in education."

Educational Reports: Reports from educational institutions, government agencies, and NGOs were examined to gain insights into the implementation and outcomes of pedagogical strategies and technologies. Sources included reports from the Nigerian Ministry of Education, UNESCO, and various educational research organizations.

Technology Reviews: Reviews of learning platforms and technological tools were sourced from technology-focused journals and websites. Information was gathered from reputable technology review sites such as TechCrunch, EdTech Magazine, and specific reviews of platforms like Khan Academy, Edmodo, and Coursera.

3.3 Data Analysis

Thematic Analysis: The data was analyzed using a thematic analysis approach to identify key trends and outcomes related to STEM education. This process involved several steps:

1. **Familiarization with Data:** Initial readings of the collected literature were conducted to gain an understanding of the content and context of each study.
2. **Coding:** Key themes and concepts were identified through coding, which involved highlighting significant statements, findings, and patterns related to the research questions.
3. **Theme Development:** Codes were grouped into broader themes that reflect the main areas of interest, such as the impact of innovative pedagogical strategies, the effectiveness of learning platforms, and the role of robotics and coding.
4. **Synthesis:** The themes were synthesized to draw conclusions about the effectiveness of different pedagogical practices and technological tools in enhancing STEM education. This synthesis aimed to highlight both successful approaches and areas needing improvement.
5. **Integration:** Findings from Nigerian and international contexts were integrated to provide a comprehensive overview of the current state of STEM education and the impact of various pedagogical and technological innovations.

This methodological approach ensures a robust analysis of existing research, providing valuable insights into how pedagogical strategies and technological tools influence STEM education.

4. Results

4.1 Impact of Innovative Pedagogy

The findings indicate that innovative pedagogical strategies significantly enhance student engagement and comprehension in STEM subjects.

***Project-Based Learning (PBL*):** Studies reveal that PBL fosters a deeper understanding of STEM concepts by allowing students to work on real-world problems. Akinloye and Adetola (2023) found that PBL promotes active learning and critical thinking, which are crucial for STEM education. Students engaged in PBL reported higher levels of motivation and interest in STEM subjects, leading to improved problem-solving skills and conceptual understanding. For instance, a project involving designing and building a simple robot resulted in increased student engagement and a better grasp of engineering principles (Chukwu & Alabi, 2021).

Flipped Classrooms: The flipped classroom model, where students first encounter new content outside of class and use class time for active learning, has shown promising results. Research by Adebayo and Akinleye (2021) suggests that this approach enhances comprehension by allowing students to learn at their own pace and apply knowledge during class activities. In Nigerian schools, the flipped model has led to improved academic performance in STEM subjects, with students benefiting from more interactive and collaborative learning experiences (Eze & Chukwu, 2023).

Inquiry-Based Learning: This strategy encourages students to explore and investigate STEM concepts through questioning and experimentation. According to Ifeoma and Okechukwu (2023), inquiry-based learning promotes deeper understanding and retention of STEM knowledge. Nigerian educators have noted that students who engage in inquiry-based activities demonstrate better problem-solving skills and higher levels of curiosity and creativity (Moses & Adesina, 2022).

4.2 Effectiveness of Personalized Learning Platforms

Personalized learning platforms have become a cornerstone in modern STEM education, offering tailored educational experiences that cater to individual student needs.

Benefits: Platforms like Khan Academy, Coursera, and Edmodo provide customized learning paths based on student performance and preferences. Akinlade and Oladipo (2023) highlighted that these platforms support differentiated instruction by adapting content to various learning styles and paces, enhancing student engagement and achievement. For example, Khan Academy's adaptive learning features help students progress through STEM topics at their own speed, ensuring that they fully understand each concept before moving on (Ojo & Ojo, 2020).

Challenges: Despite their benefits, personalized learning platforms face challenges, particularly regarding data privacy and security. Adeoye and Adeyemi (2022) reported that concerns about the collection and use of student data can hinder the adoption of these platforms in some educational settings. Additionally, the digital divide remains a significant barrier in many parts of Africa, where access to reliable internet and technology is limited (Onyeama & Afolabi, 2021).

Implementation in Nigeria: In Nigerian contexts, while platforms like Edmodo have shown promise in facilitating personalized learning, there are issues related to infrastructure and digital literacy that need addressing (Ogunyemi & Dada, 2021). The integration of these platforms in schools requires supportive policies and resources to overcome these challenges.

4.3 Integration of Robotics and Coding

Robotics and coding education have proven to be effective in enhancing students' problem-solving skills, creativity, and technical proficiency.

Robotics Education: Robotics programs provide hands-on experiences that are beneficial for learning STEM concepts. Chukwu and Alabi (2021) found that robotics education helps students develop critical thinking and teamwork skills. For instance, a study conducted in Kenyan schools demonstrated that students participating in robotics clubs exhibited improved problem-solving abilities and increased interest in STEM careers (Mugisha & Tindimwebwa, 2023).

***Coding Education*:** Coding instruction has been shown to foster logical reasoning and creativity among students. Adebayo and Akinleye (2021) reported that coding courses, even at an introductory level, significantly enhance students' understanding of programming concepts and computational thinking. In Nigerian schools, the introduction of coding curricula has led to notable improvements in students' technical skills and their ability to tackle complex problems (Okonkwo & Ibe, 2024).

Case Studies: In Nigeria, initiatives such as the STEM Robotics program in Lagos have successfully engaged students in practical STEM activities, resulting in better learning outcomes and increased interest in technology (Akinloye & Adetola, 2023). Similarly, coding bootcamps have been instrumental in developing students' technical competencies and preparing them for future STEM careers (Eze & Chukwu, 2023).

5. Discussion

5.1 Implications for STEM Education

The findings from this study highlight several key implications for the future of STEM education.

Enhanced Engagement and Learning Outcomes: The impact of innovative pedagogical strategies such as project-based learning, flipped classrooms, and inquiry-based learning underscores their effectiveness in increasing student engagement and improving learning outcomes. These strategies foster a more interactive and student-centered learning environment, which is crucial for developing critical thinking and problem-solving skills essential for STEM disciplines. The incorporation of these methods into Nigerian and broader African educational contexts can help bridge gaps in traditional teaching approaches, making STEM education more relevant and impactful (Adebayo & Akinleye, 2021).

Personalized Learning Platforms: The effectiveness of personalized learning platforms in tailoring educational experiences to individual needs demonstrates their potential in addressing diverse learning styles and paces. By offering customized learning paths, platforms like Khan Academy and Coursera can help students grasp complex STEM concepts more effectively. This adaptability is particularly important in contexts where traditional educational resources may be limited. For Nigeria and Africa, integrating these platforms into the educational system could significantly enhance STEM education by providing more accessible and individualized learning opportunities (Adeoye & Adeyemi, 2022).

Robotics and Coding Education: The integration of robotics and coding into STEM curricula has proven to be beneficial in developing students' technical skills, creativity, and problem-solving abilities. The success of robotics programs and coding initiatives in various countries suggests that similar approaches could be highly effective in Nigerian schools and other African contexts. These programs not only enhance technical competencies but also prepare students for future STEM careers, contributing to the broader goal of building a skilled workforce in the region (Chukwu & Alabi, 2021; Akinlade & Oladipo, 2023).

5.2 Challenges and Considerations

Digital Equity and Accessibility: Despite the promising results, significant challenges remain, particularly related to digital equity and accessibility. The digital divide in Nigeria and many African countries often results in unequal access to technology and online learning resources. Adeoye and Adeyemi (2022) highlight that addressing this divide is crucial for ensuring that all students can benefit from personalized learning platforms and innovative pedagogical strategies. Solutions such as investing in infrastructure, providing affordable internet access, and developing community-based technology programs could help mitigate these issues.

Data Privacy Concerns: The use of personalized learning platforms raises important concerns about data privacy and security. As noted by Adeoye and Adeyemi (2022), the collection and management of student data must be handled with care to protect privacy and prevent misuse. Educational institutions and technology providers need to implement robust data protection measures and ensure transparency in how data is used and stored. Further research into best practices for data management in educational technologies is essential to address these concerns effectively.

Implementation Challenges: The integration of robotics and coding into the curriculum also faces challenges, including the need for specialized training for educators and the cost of equipment. To address these issues, governments and educational bodies should consider funding initiatives and professional development programs to support the implementation of these technologies (Mugisha & Tindimwebwa, 2023).

6. Conclusion

6.1 Summary of the Findings

This study has highlighted the transformative potential of innovative pedagogical strategies and emerging technologies in enhancing STEM education. Innovative teaching methods such as project-based learning, flipped classrooms, and inquiry-based learning have been shown to significantly improve student engagement and learning outcomes in STEM subjects. These approaches foster an interactive and student-centered learning environment, essential for developing critical skills necessary for success in STEM fields (Adebayo & Akinleye, 2021; Akinlade & Oladipo, 2023).

The research also demonstrates the effectiveness of personalized learning platforms in providing tailored educational experiences that cater to individual learning needs. Platforms like Khan Academy and Coursera offer customized learning paths that can address diverse learning styles and paces, making STEM education more accessible and effective (Adeoye & Adeyemi, 2022). However, challenges such as data privacy concerns and the digital divide must be addressed to fully leverage these benefits.

The integration of robotics and coding into the STEM curriculum has proven to be effective in developing students' technical skills, creativity, and problem-solving abilities. Case studies from various regions indicate that robotics and coding education not only enhance technical competencies but also prepare students for future careers in STEM (Chukwu & Alabi, 2021; Akinloye & Adetola, 2023).

6.2 Recommendations

Inclusive Technologies and Pedagogical Strategies: Future research should focus on developing inclusive technologies and pedagogical strategies that cater to diverse educational needs and contexts. For instance, exploring low-cost or open-source robotics kits and coding platforms could make these tools more accessible to schools with limited resources. Additionally, research into culturally relevant pedagogical approaches can help ensure that STEM education is more inclusive and effective across different regions and communities (Onyeama & Afolabi, 2021).

Policy Support: The role of policy in supporting the integration of emerging technologies in education cannot be overstated. Policymakers need to create and implement supportive policies that promote the adoption of innovative teaching methods and technologies. This includes providing funding for technology infrastructure, supporting teacher training programs, and ensuring equitable access to educational resources (Ogunyemi & Dada, 2021). Future research should also explore how policy changes can facilitate the widespread adoption of effective STEM education practices and technologies.

Longitudinal Studies: Longitudinal studies examining the long-term impact of personalized learning platforms and robotics education on student outcomes would provide valuable insights

into their effectiveness and sustainability. Such studies could help identify best practices and inform future educational strategies and policies.

6.3 Conclusion

Ensuring that educational innovations are accessible and effective for all students requires addressing several critical challenges. These include overcoming digital equity issues, safeguarding data privacy, and providing adequate resources and training for educators. By addressing these challenges, it is possible to create an inclusive and effective STEM education environment that benefits all students, regardless of their background.

In conclusion, the integration of innovative pedagogical strategies and emerging technologies holds immense potential for transforming STEM education in Nigeria and across Africa. As educational stakeholders continue to develop and implement these innovations, it is crucial to ensure that they are accessible and equitable, so that all students have the opportunity to benefit from these advancements. Future research and policy efforts should focus on mitigating challenges and enhancing the effectiveness of these educational innovations to support the development of a skilled and knowledgeable STEM workforce.

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Article 10

Effect of Context-based Problem-Posing and Solving Instructional Approaches on Students' Problem-Posing Skills in Learning Data Handling

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Abstract

Poor students' performance and ineffective instructional approaches in mathematics education hinder the development of 21st-century skills unless powerful learning approaches that impact or influence their thinking and learning are employed. This study, therefore, aimed to investigate the effect of context-based problem-posing and solving instructional approaches on the fifth-grade students' problem-posing skills in learning data handling. This study also sought to investigate how students thought and developed problem-posing skills. To this end, the study employed a concurrent embedded quasi-experimental non-equivalent pre-test-post-test control group mixed method design. A total of 138 fifth-grade students participated in the study. Data were collected using problem-posing skills tests, lesson observations, and semi-structured interviews. Quantitative data were analyzed using descriptive statistics, paired sample t-tests, and ANCOVA. Qualitative data were analyzed thematically. The study found that context-based problem-posing and solving instructional approaches significantly outperform the traditional

teaching approach in enhancing students' problem-posing skills, with a medium effect size on the post-total data handling and post-context-type data handling problem-posing skills. Students also developed their problem-posing skills through challenging topics, comprehension of relationships, reading, interpreting images and graphs, organizing data, changing, interchanging, and comparing values. Implication of the study and future studies are discussed.

Keywords: *Context-based problem-posing and solving approaches; problem-posing skills; data handling*

1. Introduction

In this 21st century era, students need to have an innovative and creative mindset because, for education to be relevant in the twenty-first century, graduates must be creative thinkers who value teamwork and ingenuity in problem-solving (Winaryati, 2021). Mathematics is crucial to our everyday lives, for expanding our knowledge, for scientific and technological exploration, and for explaining the world. These contemporary students' anticipated skills can be developed through mathematics education, specifically from kindergarten until middle school (Suyitno & Suyitno, 2018). As a result, students need to grow with a strong grounding in mathematics. In this regard, many changes have been made to mathematics education as a result of data on students' mathematical performance from a variety of local and global studies. These changes primarily involve a shift from teacher-centered to student-centered practices, behaviorism to constructivism, and the sociocultural paradigm (Van de Walle et al., 2019).

Learning mathematics in context is crucial for practical applications and scientific exploration. Particularly, data handling in mathematics education is crucial for real-world scenarios, critical thinking development, and creating a mathematics-literate society (Naidoo & Mkhabela, 2017). Data handling creates links between probability, statistics, and other mathematical topics as well as several multidisciplinary fields (Mutlu & Sarı, 2019). To this end, data handling is an essential primary mathematics content domain that students will utilize and expand upon throughout their schooling (Julius et al., 2018). Through data-handling, students develop skills to collect, organize, display, analyse, and interpret numeric data (Wessels, 2022). One aspect of school mathematics standard for grade 3-5 is posing questions that can be addressed with data and collect, organize, and display relevant data to answer them (National Council of Teachers of Mathematics, 2000). The National Council of Teachers of Mathematics emphasizes the importance of posing questions about themselves, their environment, school or community issues, and the subject areas they are studying at these grade levels. However, the desired higher order functioning in data handling still requires significant progress (Watson & Callingham, 1997). Besides, international assessments reveal that students are not performing well in data handling across the world (Naidoo & Mkhabela, 2017).

Problem-posing along with problem-solving has recently become one of the key elements for the teaching and learning of mathematics (Leavy & Hourigan, 2020). Problem-posing is the process of generating or re-generating a solvable, reasonable, new, and complex mathematical problem based on the given information (Cohen, 2015). In contrast to the custom of solving problems that others have posed, problem-posing is the act of inventing one's own problem (Kopparla et al., 2019). This view supports the belief that a problem becomes a problem for a student when the student sets his or her own problem for himself or herself. The majority of elementary school students successfully solved problems that they generated (Martinez & Blanco, 2021). Problem-posing needs to be infused into mathematics education as a means of instruction and a means of enhancing students' problem-posing skills at all grade levels around the world (Singer et al., 2013). Enhancing students' ability to pose problems has a beneficial impact on their ability to solve problems, think critically, and be creative (Kul & Çelik, 2020; Singer et al., 2015). Problem-posing is powerful to explore the interaction between the cognitive and affective dimensions of students' mathematical learning (Silver, 1994). In the classroom, posing problems can improve students' learning outcomes and provide them the opportunity to create mathematical problems in a practical setting (Bevan & Capraro, 2021). It is still necessary to improve the problem-posing skills of elementary school students by offering specific facilitation that gives them the confidence to raise problems (Isrokatun et al., 2019).

There is a growing need for different teaching methods that impact students' engagement in learning mathematics in general (Alrajeh & Shindel, 2020; Lee & Paul, 2023) and data handling in particular (Chua & Toh, 2022). Studies have shown that problem-posing interventions have a positive and significant impact on problem-posing skills, problem-solving skills, critical thinking skills, attitudes, and understanding of mathematical topics (Divrik, 2023; Kaur & Rosli, 2021; Kul & Çelik, 2020). The limited problem-posing interventions (Chen et al., 2015; Kopparla et al., 2019; Ozdemir & Sahal, 2018) and both problem-posing and problem-solving interventions (Bevan & Capraro, 2021; Bonotto & Santo, 2015; Kopparla et al., 2019; Martinez & Blanco, 2021) suggest that context-based problem-posing and solving instructional approaches may have the most significant impact on students' problem-posing skills in learning data handling. Therefore, the present study employed context-based problem-posing and solving instructional approaches by integrating context-based instruction with problem-posing and problem-solving instructional approaches to provide an empirical explanation of how context-based problem-posing and solving instructional approaches might enhance students' problem-posing skills in learning data handling in an Ethiopian context.

Context-based instructional approaches are useful for teaching mathematics as well as for applying the subject to real-world problems and scenarios (Heuvel-Panhuizen, 2005). In this regard, the present study used Relating, Experiencing, Applying, Cooperating, and Transferring (REACT) teaching strategies (Crawford, 2001) due to several reasons. First, prior research studies have found that REACT teaching strategies are one of the most effective pedagogical approaches for improving students' conceptual understanding (Sari & Darhim, 2020); creativity (Qadri et al., 2019); problem-solving ability (Arfiani et al., 2020); and mathematics achievement (Mutakin,

2021). Second, the components of the REACT teaching strategies can be applied independently or together, which might be good for managing the time and the learning contents. Third, the REACT strategies are suitable to build relational understanding of the learning concept, a development path from lower-order thinking skills to higher-order thinking skills (Herlina & Ilmadi, 2022).

Based on the notion and the purposes of problem-posing, varieties of problem-posing models exist in the literature, such as before, during, and after solution problem-posing (Silver, 1994); editing, selecting, comprehending, and translating (Christou et al., 2005); artifacts as prompts (Cohen, 2015); and "find-a-pattern problem-solving strategy" (Kılıç, 2017, p. 778). To this end, considering the problem-posing approaches: pre-solution posing (Silver & Cai, 1996), editing, translating (Christou et al., 2005), cultural artifacts (Cohen, 2015), and probability or prediction-based problems (Kılıç, 2017), the present study adapted a model of problem-posing based on artifacts with editing, problem-posing based on a specific learning domain, problem-posing based on artifacts with translating, and problem-posing based on editing with a prescribed problem-solving strategy (predicting). These problem-posing approaches were adapted in the present study for two major reasons. First, the problem-posing approach is based on the nature of the problem-posing process, which is suitable to the learning domain (data handling) and the information provided for varying levels of challenge and possibilities for generating problems (Abu-Elwan, 2002). In other words, the problem-posing process entails the processes of classifying, understanding, organizing, and unifying the possessed information to pose a problem statement (Tavşanli et al., 2018). Second, these approaches were adapted based on the literature gap and from problem-posing approaches implemented on primary and middle school students for the purpose of investigating students' problem-posing skills.

Concerning the problem-solving approach, the current study employs a modification of the Krulik and Rudnik models (Kusdinar et al., 2017). (1) Read and think; (2) Explore and plan; (3) Select strategies; (4) Find and answer; (5) Reflect and extend. The present study uses this approach because, in the Krulik and Rudnick model of problem solving, approaches emphasize the importance of reflection and extension of the answers to another situation, which has been given by developing Polya's heuristics to five stages of problem solving (Suryaningsih, 2019). Besides, this approach to problem solving can be a basis for scaffolding in teaching with a problem-solving approach (Kusdinar et al., 2017).

1.2. Theoretical Frame Work

Based on the prior research (Christou et al., 2005; Cohen, 2015; Kılıç, 2017; Kusdinar et al., 2017; Ozdemir & Sahal, 2018; Sari & Darhim, 2020), the context-based problem-posing and solving instructional approaches were guided by the integration of social constructivism and socio-cultural theories (the concept of ZPD and scaffolding) to investigate students' problem-posing skills in learning data handling. In a data handling mathematics lesson, the teacher would present a context-based problem-posing and problem-solving task and ask students to pose and solve mathematics

problems starting from that task. In the process of context-based problem-posing and solving, students generate and solve new problems and build their knowledge from prior knowledge based on the given context. This process was facilitated through small-group discussion and reflection. This process is at the heart of social constructivism. Besides, in the process of context-based problem-posing and solving, the concept of problem-posing tasks is new for students, and the problem-posing and solving activities might not be managed individually by each student, but each student can manage the problem-posing and solving tasks with the help of more capable peers or their teacher. In this case, therefore, applying Vygotsky's Zone of Proximal Development Theory (ZPD) is relevant for the student to accomplish the problem-posing and solving task and internalize the related new learning concept (Christmas et al., 2013). To do that, the practice of scaffolding was vital for those students who couldn't do the context-based problem-posing and solving tasks alone. Hence, during context-based problem-posing and solving tasks, the teacher encourages and scaffolds students to pose appropriate problems by providing the right amount of support using focused questions and feedback, cooperating, and reflection until students become more comfortable with the provided task, then the scaffolds will be removed, and the student becomes more independent (Van de Walle et al., 2019).

1.3. Statement of the problem

In Ethiopia, many efforts and actions have been made in the education sector in general and mathematics education in particular. The international education movement toward the inclusion of problem-solving is clearly placed as one of the core competencies in the primary mathematics curriculum (Ministry of Education, 2020). Besides, the curriculum suggests learner-centered approaches that engage them relevantly in their learning (Ministry of Education, 2020). The current primary mathematics curriculum prioritizes core competencies such as learning to learn, critical thinking, problem-solving, reasoning, creativity, innovation, collaboration, communication, and leadership for 21st-century student learning (Ministry of Education, 2021). However, over the last two decades, students' mathematics performance has been observed below the expected 50% national standard, according to the national learning assessment report (Figure 13)

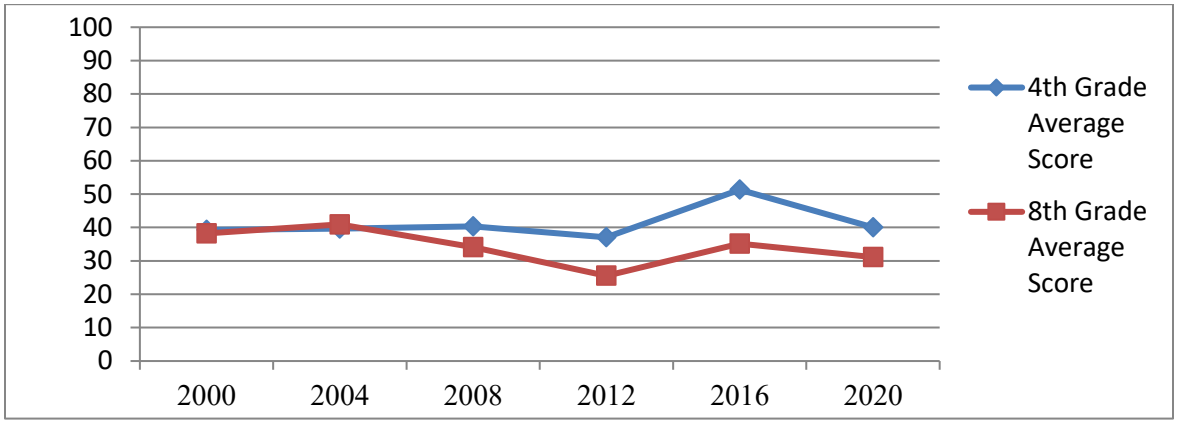


Figure 13: National Average Mathematics Scores by Year and Grade Levels

Source: (Belay et al., 2016; National Educational Assessment and Examinations Agency (NEAEA), 2016, 2020)

These results (Figure 13) depict that low student performance in mathematics has persisted for the last two decades in primary and middle schools. This suggests that students have been challenged to solve mathematical problems. In particular, grade 4 students scored the lowest in data handling (30.06%), while grade 8 students had the highest average score in the data/probability content domain (37.11%) on the sixth national learning assessment of Ethiopian students in grades four and eight (National Educational Assessment and Examinations Agency, 2020). In addition, studies have shown that ineffective instructional approaches, particularly teacher-centered approaches, persist in actual classroom lessons (Begna, 2017; Frost & Little, 2014; Takele, 2020). These Ethiopian problems suggested that students were performing poorly in mathematics generally and in data handling in particular, which is frequently linked to teacher-centered instruction. I am therefore motivated to carry out the intervention for a variety of reasons.

First, these learning experiences, poor students' mathematics performance and ineffective instructional approaches, provide little premises to create students that possess the required intended skills unless we employ an intervention using context-based problem-posing and solving instructional approaches (Leavy & Hourigan, 2020; Singer et al., 2013; Van de Walle et al., 2019). Second, problem-posing has not yet been recognized and practiced in the Ethiopian education system; however, the existing empirical studies conducted across the world but not in Ethiopia suggest that problem-posing interventions have a beneficial and significant effect on problem-posing skills, problem-solving skills, critical thinking skills, attitudes, confidence, and understanding of mathematical topics (Divrik, 2023; Kaur & Rosli, 2021; Kul & Çelik, 2020) in particular and science and mathematics education in general (Akben, 2020). Third, there does not seem to be any systematic or empirical research on problem-posing instructional methodologies in mathematics education in the setting of Ethiopia, based on a thorough review of the empirical literature.

Fourth, pre-service and in-service math teachers have been the subject of the majority of research on problem-posing approaches (Kaur & Rosli, 2021; Kılıç, 2017; Silver et al., 1996). This is understandable given that teachers must possess the necessary problem-posing and problem-solving abilities. However, limited empirical investigation focused on how elementary school students learn mathematics using problem-posing instructional approaches (Christou et al., 2005; Cohen, 2015; Kertiyani et al., 2023).

Fifth, the limited problem-posing interventions (Chen et al., 2015; Kopparla et al., 2019; Ozdemir & Sahal, 2018) and both problem-posing and problem-solving interventions (Bevan & Capraro, 2021; Bonotto & Santo, 2015; Kopparla et al., 2019; Martinez & Blanco, 2021) were employed to enhance students' problem-posing skills. However, it appears that no previous research has been done on the potential benefits of implementing context-based problem-posing and solving instructional approaches in primary mathematics classrooms with regard to students' problem-posing skills in learning data handling. Therefore, to address the actual problem and the research gap, this study examined how context-based problem-posing and solving instructional approaches influence primary school students' problem-posing skills in learning data handling in Addis Ababa, Ethiopia. The findings of this study have the potential to contribute to the literature and to the body of local knowledge by demonstrating how context-based problem-posing and solving instructional approaches significantly outperform traditional teaching approaches in enhancing students' problem-posing skills in learning data handling.

1.4. Objective and Research Questions of the Study

The objective of this study was to investigate the effect of context-based problem-posing and solving instructional approaches on the fifth-grade students' problem-posing skills in learning data handling in Addis Ababa, Ethiopia. To this end, the structure and focus of this research were guided by the following research questions

I. Are there significant differences in students' pre- and post-tests of problem-posing skills within each intervention and control group?
II. Are there significant differences in students' problem-posing skills in learning data handling among the two intervention and control groups using the pre-test as a covariate?
III. How students thought and developed problem-posing skills in learning data handling?

2. Materials and Methods

2.1. Research Design and Methods

This study employed a concurrent embedded quasi-experimental non-equivalent pre-test-post-test control group mixed method design, QUAN (qual) (Creswell, 2014). The reason for adapting this design was that this design allows the researcher to collect both quantitative and qualitative data simultaneously, with big quantitative data using a quasi-experimental, non-equivalent pre-test-post-test control group design and supportive qualitative data collected to embed into the big quantitative data and examine how participants in treatment groups are experiencing the

intervention (Cresswell, 2012). This design is relevant to better understand how context-based problem-posing and solving instructional approaches influence students' problem-posing skills, problem-solving skills, attitudes and engagement in learning data handling. Because it facilitates the investigator's interpretation of experimental results through the incorporation of individual perspectives within the context of an experimental intervention (Creswell & Creswell, 2018). In addition, because the study was conducted in intact classrooms that were operational and adhered to the regular academic calendar of governmental schools, it was not feasible to divide the children into groups at random. Hence, the design was suitable for intact classrooms, as random grouping was not feasible

2.2. Respondents and Sampling techniques

This study was conducted at three governmental primary schools with a total of 138 fifth-grade students in different sub-cites of Addis Ababa, Ethiopia. Initially, from a total of 11 sub-cities, four sub-cites were selected using simple random sampling lottery methods. Then, from each selected sub-cite, using the purposive sampling method based on teachers' willingness to support the implementation process of the pilot study and the interventions during their academic calendar, proximity of teachers teaching experience, and their qualifications, one school for the pilot study and three schools (one section from each school) were selected for the experimental and control groups.

Finally, once the three groups were selected, the experimental group 1, experimental group 2, and comparison group were assigned using the simple random sampling lottery method. To this end, experimental group 1, experimental group 2, and comparison group teachers are all female, have a Bachelor of Education in Mathematics, and have 14, 12, and 14 years of teaching experience, respectively. Besides, from the context-based problem-posing and solving instructional approaches group, five interview participants (three males and two females) were selected based on the pre-test problem-solving results using maximum variation sampling techniques. Maximum variation sampling is a purposeful sampling technique that helps select some units or cases to maximize the diversity relevant to the research questions (Divrik, 2023). To this end, pre-problem-solving test results and gender were used as sources of variation. Interviews were conducted repeatedly at the beginning, middle, and end of the intervention.

2.3. Instruments of Data Collections

The researcher prepared problem-posing skills pre-test and posttest to measure students' problem-posing skills at the beginning and end of the intervention. Each test consists of 5 problem posing tasks on the data handling of grade 5 mathematics contents. Firstly, to develop the problem-posing skills test items, prior research has been considered in preparing problem-posing tasks associated with the required problem-posing approaches (Christou et al., 2005; Cohen, 2015; Kılıç, 2017; Silver, 1994) and in measuring students' problem-posing skills (Cankoy & Özder, 2017; Cohen,

2015; Rosli et al., 2013). Then, for each pre-test and post-test, three context-type data handling problem-posing skill tasks and two non-context-type data handling problem-posing tasks were prepared based on the table of specifications. Furthermore, 4 problem-posing tasks were developed for the purpose of task based-interview of students during intervention to investigate their thoughts and strategies to develop problem-posing skills.

To measure students' problem-posing skills, different assessment approaches have been used in the literature. A performance rubric is more comprehensive for assessing students' problem-posing skills due to the openness of the problem-posing tasks (Rosli et al., 2013). As a result, the present study adapts a performance rubric to measure students' problem-posing skills (Appendix 1) based on the categories of solvability, reasonability, creativity, complexity by steps, complexity by type, and scoring points from 0, 1, 2, 3, and 4 based on the criteria for each aspect (Cankoy & Özder, 2017; Cohen, 2015; Rosli et al., 2013). Therefore, each category of a problem-posing task was scored out of four based on the problem-posing skills evaluation rubric. Since each test consisted of three context-type problem-posing tasks and two non-context-type problem-posing skills tasks, the average of each category of the total items was calculated out of four, and the sum of the average scores of each category was the total score of the individual. Since there are 5 subcategories of the problem-posing task rubric, each student's raw score was out of 20. Finally, for the sake of statistical analysis, each individual raw score was converted to 100.

Additionally, the researcher prepared a classroom observation checklist. The lesson observation checklist was prepared based on the existing literature (Chen et al., 2015; Cohen, 2015). The observations were focused on aspects of students' context-based problem-posing classroom practices. The researcher continuously observed 10 data handling lessons to get data to answer how the context-based problem-posing and solving instructional approaches influences their thought of developing problem-posing skills.

Furthermore, in order to get data to answer the research question regarding how students thought and developed problem-posing skills in learning data handling through context-based problem-posing and solving instructional approaches, the researcher employed semi-structured task based interview. The interview questions focused the process of problem-posing skills in learning data handling. The questions mainly focused on how they came up with the problem-posing process. The task-related interview questions were prepared based on the existing literature (Chen et al., 2015; Cohen, 2015). Students' work was used for task-related interviews. Task-related interviews provide deep insight into the unique ways that elementary students approach the problem posing and solving process (Cankoy & Özder, 2017; Cohen, 2015). The researcher carried out the interview at the beginning, in the middle, and at the end of the intervention. To prevent any loss of class time, each stage of the interview was conducted in person and took between seven to fifteen minutes for each student during the school break. With permission from the participants, audio recordings were used as a means of data collection, and students were asked the same questions at the beginning, middle, and end of the intervention.

2.4. Validity and Reliability of the Instruments

To ensure the validity of the instrument, face, content, and construct were validly employed. Before preparing the problem-posing skills test items, prior research has been considered in measuring students' problem-posing skills (Cankoy & Özder, 2017; Cohen, 2015; Rosli et al., 2013) and preparing problem-posing tasks associated with the required problem-posing approaches (Christou et al., 2005; Cohen, 2015; Kılıç, 2017a; Silver, 1994). Then, for each pre-test and post-test, three context-type data handling problem-posing skill tasks and two non-context-type data handling problem-posing tasks were prepared by the researcher based on the table of specifications. To ensure face and content validity, the draft of problem-posing skills pre- and post-tests has shown primary mathematics teachers, mathematics expertise from educational bureaus, and the ministry, particularly, were involved in the preparation of mathematics curriculum repeatedly after being translated from English into Amharic. Besides, the research supervisors' comments and suggestions have been taken to improve the problem-posing skills pre- and post-test. Furthermore, a problem-posing skill pre- and post-test was piloted, and an item analysis was conducted.

Item difficulty and item total correlation are considered statistical criteria for assessing and improving the quality of test items. "For items that are not scored dichotomously but instead take a range of score point values, the item difficulty is the proportion of points earned out of a total of possible item points" (Fein, 2012, p. 150). The average or medium difficulty, $0.25 \leq p \leq 0.75$, will permit more reliable discrimination among the examinees of nearly all ability levels than will a collection of items with a wider spread of difficulties (Crocker & Alegina, 1986). Therefore, the problem-posing skills pre- and post-test task items were evaluated and improved using the following criteria: item difficulty to pose between 0.3 and 0.75 and item-total correlation (correlation between item score and test score) significantly greater than 0.00 (Crocker & Alegina, 1986; Fein, 2012; Wijayanti, 2020). Minor changes have been made based on some unclarity for students observed by the researcher during the test administration for the pilot study, item analysis results, and mathematics expertise suggestions in relation to students learning. In general, the problem-posing skill pre- and post-tests are generally comparable and functioning well, according to the item analysis.

Lesson observation was guided by a lesson observation checklist, evaluated by the respected research supervisors. The researcher was a non-participant observer, and hence, in each lesson observation, the researcher recorded a memo supported by the checklist and evaluated it as observable, somewhat observable, and non-observable. Furthermore, to confirm the trustworthiness of interview data, the researcher made an attempt to listen attentively to the interviewee with the support of audio recordings. The interview was conducted in Amharic, and the audio was transcribed into Amharic text first and shown to the interviewee at each stage of the interview, then the Amharic interview text was translated into English text using proficient experts.

2.5. Procedures

Preparation phase: after finalizing the data collection tools and selection of participants, the researcher prepared intervention training guidelines and provided training on context-based problem-posing and solving instructional approaches to the Experimental Group 1 teacher for 12 hours and 40 minutes and problem-posing and solving instructional approaches to the Experimental Group 2 teacher for 12 hours and 40 minutes separately using Amharic language according to the curriculum. Besides, the context-based problem-posing and solving instruction approaches guideline and sample lesson plan were given to the experimental group 1 teacher. The problem-posing and solving instructional approaches guideline and sample lesson plan were given to the teacher of experimental group 2. Finally, before intervention, a problem-posing skill pre-test was administered to all three groups.

Implementation phase: Experimental Group 1 was taught data handling through context-based problem-posing and solving approaches. This learning approach involves the integration of the REACT (relating, experiencing, applying, cooperating, and transferring) teaching approaches with problem-posing and solving approaches. The major stages of the classroom activities that comprise these methods are as follows: First, the teacher introduces a lesson by providing a context-based problem-posing task and encouraging students to pose their own problems. Students relate the new concept to one's experience or with their prior knowledge by posing their own problems. Second, the teacher then encourages students to experience creating more problems and applying the new concepts in small groups, scaffolding them with focused questions. Third, the teacher observes each student's work and encourages group discussions and reflection. Finally, the teacher provides a problem or selects a student's problem and requests that students solve it individually, in groups, and according to the problem-solving steps. Students reflect on their work and discuss it with the whole class in relation to the provided problem.

Experimental group 2 learned data handling using problem-posing and solving instructional approaches. The REACT strategy was not considered in problem-posing and solving approaches. The approach involves presenting a problem-posing task, revising the lesson by posing oral problems, and generating their own problems based on the provided learning content in small groups. The teacher scaffolds students with focused questions, ensuring all problems are mathematical and relevant to the learning content. Finally, the teacher provides a problem or selects a student's problem and requests that students solve it individually, in groups, and according to the problem-solving steps. Students reflect on their work and discuss it with the whole class. The comparison group was left to be taught with the usual teaching and learning approach (traditional approach).

The process of intervention on the learning content of data handling—collection of data handling, construction and interpretation of bar graphs and line plots, average numbers, and simple experiments using coins, lottery, and dice—lasted for six weeks. At the end of the interventions, the problem-posing skill post-test was administered to the experimental and comparison groups.

2.6. Methods of Data Analysis

A paired sample t-test was employed to investigate whether there are significant differences in the mean gains of the pre-test and post-test of problem-posing skills in learning data handling in each group, and an ANCOVA test was carried out to investigate whether there are statistical mean differences in students' problem-posing skills (PPS) in learning data handling among the three groups while statistically controlling students' pre-problem-posing skills test. Assumptions of ANOVA, paired sample t-test, and ANCOVA were checked. These are 1) Observations are independent: The data scores of the individuals are independent of each group since each group of the study was found in different sub-cities of Addis Ababa and the individual's scores are independent; 2) Homogeneity of variances: variances on the dependent variable are equal across groups; and 3) Normality: the dependent variable is normally distributed for each group; 4) Linear relationship between the covariates and the dependent variable: a matrix scatter plot was checked for the linear relationships between the dependent variables and the covariates at each group level, and the covariates and the dependent variables have a linear relationship; 5) Homogeneity of Regression Slopes: the interaction of the group and the covariate was not significant for each covariate, so the factor (the context-based problem-posing and solving instructional approach group, the problem-posing and solving instructional approach group, and the comparison group) and the covariates (pre-total data handling PPS, pre-context-type data handling PPS, and pre-non-context-type data handling PPS) do not significantly interact; and 6) Homogeneity of variances of the dependent variables controlling the covariates is equal across groups. Regarding the normality of the quantitative data, the skewness and the kurtosis of the data in the experimental and control groups are all between -1 and 1. The skewness and kurtosis of the data suggest that the quantitative data are approximately normal (Hatem et al., 2022; Orcan, 2020). Besides, percentage was used to describe lesson observation results. Qualitative data obtained from students' interviews was analyzed thematically. In order to identify recurring themes, the qualitative data from the transcription was then coded and arranged in accordance with the questions and each stage of the interview. To confirm the dependability of the qualitative data, the researcher made an attempt to gain sound feedback from a non-participant researcher regarding the procedure of data collection, analysis, and the results of the study. Besides, to confirm authenticity, three independent classroom teachers employed for experimental and control group teachers. Furthermore, to confirm the trustworthiness of interview data, I first conducted the interview in Amharic and then made an attempt to listen attentively to the interviewee with the support of audio recordings. Then, I transcribed the audio into Amharic text and presented it to the interviewee at each stage of the interview. Next, I employed proficient experts to translate the Amharic interview text into English.

3. Results

The analysis result and interpretation of the data with respect to the study that sought to address

each research question are presented as follows:

3.1. A Pair Sample T-Test Result on Students' Mean Gain on problem-posing skills

The descriptive statistics and paired sample t-test results of the pre- and post-total data handling PPS , context type, and non-context type data handling PPS in learning data handling within each group are presented in Table 2 and

Table 3 below.

Table 2: Descriptive statistics of pre-test and post-test of problem-posing skills in learning data handling by groups

Dependent Variable	Type of Test	Groups								
		Context-based problem posing and solving instructional approaches			Problem posing and solving instructional approaches			Comparison Group		
		N	M	SD	N	M	SD	N	M	SD
Total data handling PPS	pre	□□	□□□□□	□□□□□	□	□□□□	□□□□	□	□□□□	□□□□
	Post	□□	□□□□□	□□□□□	□	□□□□	□□□□	□	□□□□	□□□□
Context-type data handling PPS	pre	□□	□□□□□	□□□□□	□	□□□□	□□□□	□	□□□□	□□□□
	Post	□□	□□□□□	□□□□□	□	□□□□	□□□□	□	□□□□	□□□□
Non-context-type data handling PPS	pre	□□	□□□□□	□□□□□	□	□□□□	□□□□	□	□□□□	□□□□
	Post	□□	□□□□□	□□□□□	□	□□□□	□□□□	□	□□□□	□□□□

Table 3: **Paired samples t-test analysis result on students' mean gain on problem-posing skills**

Group	Paired Differences	T	Df	P

Mean gain of Subjects		M	SD			
Total Data handling PPS: Pre-Post	Context-based problem posing and solving instructional approaches	12.9184	11.8968	7.601	48	.000
	problem posing and solving instructional approaches	11.6444	14.8188	5.271	44	.000
	Comparison Group	5.6364	12.7354	2.936	43	.005
Context type Data handling PPS: Pre-Post	Context-based problem posing and solving instructional approaches	13.7749	16.5438	5.828	48	.000
	problem posing and solving instructional approaches	9.3327	18.1064	3.458	44	.001
	Comparison Group	2.8409	13.6375	1.382	43	.174
Non-context type Data handling PPS: Pre-Post	Context-based problem posing and solving instructional approaches	14.7449	16.0909	6.414	48	.000
	problem posing and solving instructional approaches	16.6667	17.9488	6.229	44	.000
	Comparison Group	8.0682	17.7831	3.009	43	.004

The descriptive statistics (Table 2) showed that students' total data handling PPS, context-type data handling PPS, and non-context type data handling PPS mean scores increased from their pre-test mean scores in each group. The context-based problem-posing and solving instructional approaches group had the largest mean score increment on total data handling PPS (12.92) and context-type data handling PPS (13.77). Besides, the problem-posing and solving instructional approaches group had the largest mean score increment on non-context type data handling PPS (16.67). Whereas, comparison group students' mean scores increment in all types of problem-posing skills were the lowest compared to the experimental groups.

A paired t-test result (

Table 3) shows that the mean gains of the pre-test and post-test of students' total data handling PPS ($T(48) = 7.601$, $p = .000$, $d = 0.80$), context-type data handling PPS ($T(48) = 5.828$, $p = .000$, $d = 0.77$) and non-context type data handling PPS ($T(48) = 6.414$, $p = .000$, $d = 0.93$) in learning data handling were statistically significant in the context-based problem-posing and solving instructional approaches group. The effect size of the context-based problem-posing and solving instructional approaches group on total data handling PPS, context-type data handling PPS, and non-context-type data handling PPS was 0.80, 0.77, and 0.93, respectively. According to the standard suggested by Cohen's (1988) guidelines, 0.80, 0.77, and 0.93 are large, medium, and large treatment effects, respectively.

Besides, the mean gains of the pre-test and post-test of students' total data handling PPS (T(44) = 5.271, p =.000, d = 0.65), context type data handling PPS (T(44) = 3.458, p =.001, d = 0.54), and non-context type data handling PPS (T(44) = 6.229, p =.000, d = 0.86) in learning data handling were statistically significant in the problem-posing and solving instructional approaches group. The effect sizes of the problem-posing and solving instructional approaches group on total data handling PPS, context-type data handling PPS, and non-context-type data handling PPS were 0.65, 0.54, and 0.86, respectively. According to the standards suggested by Cohen's (1988) guidelines, these are medium, medium, and large treatment effects, respectively.

Furthermore, the mean gains of the pre-test and post-test of students' total data handling PPS (T(43) = 2.936, p =.004, d = 0.43) and non-contextual-type data handling PPS (T(43) = 3.009, p =.004, d = 0.52) in learning data handling were statistically significant in the comparison group. However, the mean gain of students' context-type data handling PPS in learning data handling was not statistically significant in the comparison group (T(43) = 1.382, p =.174). The effect sizes of the comparison group on total data handling PPS and non-context-type data handling PPS were 0.43 and 0.52. These are small and medium levels of effect sizes, respectively, according to Cohen's (1988) guidelines.

3.2. Analysis of Covariance using Pre-test as a Covariate

The summary of the three groups' adjusted and unadjusted means and variability and analysis of covariance (ANCOVA) results are presented in Table 4 and Table 5 below.

Table 4: Adjusted and Unadjusted means and variability of problem-posing skills

Type of Questions	Groups	N	Unadjusted		Adjusted	
			M	**SD**	**M**	**SE**
Total Data handling PPS: Pre-Post	Context-based problem-posing and solving instructional approaches	49	54.1020	16.0912	53.963	1.714
	Problem posing and solving instructional approaches	45	54.2889	17.9743	53.193	1.792
	Comparison Group	44	44.6591	13.2243	45.935	1.813
Context type Data handling PPS: Pre-Post	Context-based problem posing and solving instructional approaches	49	58.6049	17.8779	59.025	2.010
	Problem posing and solving instructional approaches	45	56.9627	17.2079	55.863	2.101
	Comparison Group	44	47.2345	15.9129	47.891	2.122

Non-context type Data handling PPS: Pre-Post	Context-based problem-posing and solving instructional approaches	49	48.3163	15.7816	48.333	2.094
	Problem-posing and solving instructional approaches	45	51.1667	19.2738	50.736	2.186
	Comparison Group	44	40.7955	15.5123	41.218	2.211

Table 5: Analysis of Covariance result on problem-posing skills using Pre-test as a Covariate

Type of Questions	Source	Df	Ms	F	P	Eta^2
Total data handling PPS: Pre-Post	Pre-test	1	14871.893	103.300	.000	.435
	Groups	2	880.532	6.116	.003	.084
	Error	134	143.968			
Context type data handling PPS: Pre-Post	Pre-test	1	12753.051	64.472	.000	.325
	Groups	2	1502.980	7.598	.001	.102
	Error	134	197.807			
Non-context type data handling PPS: Pre-Post	Pre-test	1	9850.858	45.840	.000	.255
	Groups	2	1089.682	5.071	.008	.070
	Error	134	214.897			

The context-based problem-posing and solving instructional approaches group had the biggest adjusted mean (Table 4) on post-total data handling PPS (M = 53.96) and post-context type data handling PPS (M = 59.03) after the influence of the pre-test was statistically excluded. Furthermore, the group that taught data handling through problem-posing and solving instructional approaches demonstrated the highest adjusted mean score (M = 50.74) for post-non-context type data handling problem-posing skills. In contrast to the experimental groups, the comparison group students adjusted mean scores in every category of problem-posing skills were the lowest.

From the ANCOVA Table 5 above, the covariates: pre-test of total data handling PPS, context type data handling PPS, and non-context type data handling PPS have a significant effect on the experimental and control groups ($F(1,134) = 103.300$, $P = .000$, $Eta^2 = .435$), ($F(1,134) = 64.472$, $P = .000$, $Eta^2 = .325$), and ($F(1,134) = 45.840$, $P = .000$, $Eta^2 = .255$), respectively.

After controlling the covariates (pre-total data handling PPS, pre-context-type data handling PPS, and pre-non-context-type data handling PPS), the ANCOVA result (Table 5) depicted that there were significant differences in students' post-total data handling PPS ($F(2,134) = 6.116$, $p = 0.003$, Eta2 =.084), post-context type data handling PPS ($F(2,134) = 7.598$, $p = 0.001$, Eta2 =.102), and

post-non-context type data handling PPS (F (2,134) = 5.071, p = 0.008, Eta2 =.070), respectively, in learning data handling among the experimental and control groups. The partial Eta squared (Eta2) value indicates the effect size and describes how much of the variance in the dependent variable is explained by the independent variable (Gravetter & Wallnau, 2017). Thus, the proportion of the variance of total data handling PPS explained by the groups (experimental and comparison groups) is 8.4%, the proportion of the variance of post-context-type data handling PPS explained by the groups is 10.2%, and the proportion of the variance of post-non-context type data handling PPS explained by the groups is 7%. According to Cohen (1988), the variance of post-total data handling PPS, context-type data handling PPS, and non-context-type data handling PPS has a medium effect size.

Generally, after the influence of the pre-test was statistically removed, the results of the ANCOVA test indicated that there were statistically significant differences in post-total data handling PPS, post-contextual type data handling PPS, and post-non-contextual type data handling PPS among the groups.

For the purpose of pair-wise multiple comparisons and to check which specific group means of total data handling PPS, contex-type data handling PPS, and non-context-type data handling PPS in the posttest have made significant differences with the other group, it was essential to look back and employ the post hoc test. Since the Levene test was not significant on post-total data handling PPS, post-context type data handling PPS, and post-non-context-type data handling PPS, the Tukey HSD test was employed and presented in

Table **6** below.

Table 6: The Tukey HSD test analysis result on post-problem-posing skills by groups

Dependent Variable	(I) Group	(J) Group	MD (I-J)	SE	P
Post-Total Data handling PPS	Experimental Group1	Experimental Group 2	-.1869	3.2845	.998
		Comparison Group	9.4430*	3.3039	.014
	Experimental Group 2	Comparison Group	9.6298*	3.3727	.014
Post-Context type Data handling PPS	Experimental Group1	Experimental Group 2	1.6417	3.5210	.887
		Comparison Group	11.3704*	3.5418	.005
	Experimental Group 2	Comparison Group	9.7287*	3.6155	.022
Post-non-context type Data handling PPS	Experimental Group1	Experimental Group 2	-2.8503	3.4934	.694
		Comparison Group	7.5209	3.5141	.086
	Experimental Group 2	Comparison Group	10.3712*	3.5872	.012

From the Tukey HSD Test result (
Table 6), there was a statistically significant difference in students' mean scores of post-total data handling PPS and post-context-type data handling PPS in learning data handling between the context-based problem-posing and solving instructional approaches group and the comparison group (MD = 9.44, p =.014, d =.64) and (MD = 11.37, p =.005, d =.67), respectively. Besides, there was a statistically significant difference in students' mean scores of post-total data handling PPS, post-context type data handling PPS, and post-non-context type data handling PPS in learning data handling between the problem-posing and solving instructional approaches group and the comparison group (MD = 9.63, p =.014, d =.61), (MD = 9.72, p =.022, d =.59), and (MD = 10.37, p =.012, d =.59), respectively. However, there was no statistically significant difference in students' mean scores of post-total data handling PPS, post-context-type data handling PPS, and post-non-context-type data handling PPS between the experimental groups (MD = -.19, p > 0.05), (MD = 1.64, p > 0.05), and (MD = -2.85, p > 0.05), respectively.

The effect sizes between the context-based problem-posing and solving instructional approaches group and comparison group on pots-total data handling PPS and post-context type data handling PPS were.64 and.67, respectively. According to the standard suggested by Cohen's (1988) guidelines, these effect sizes show a medium treatment effect. Moreover, the effect size between the problem-posing and solving instructional approaches group and the comparison group on pots-total data handling PPS, post-context type data handling PPS, and post-non-context type data handling PPS was.61,.59, and.59, respectively. These effect sizes show a medium treatment effect, according to Cohen's (1988) guidelines.

3.3. Lesson observation Result

Students' context-based problem-posing and solving practices in learning data handling based on 10 actual classroom lesson observations are presented in Figure 14below.

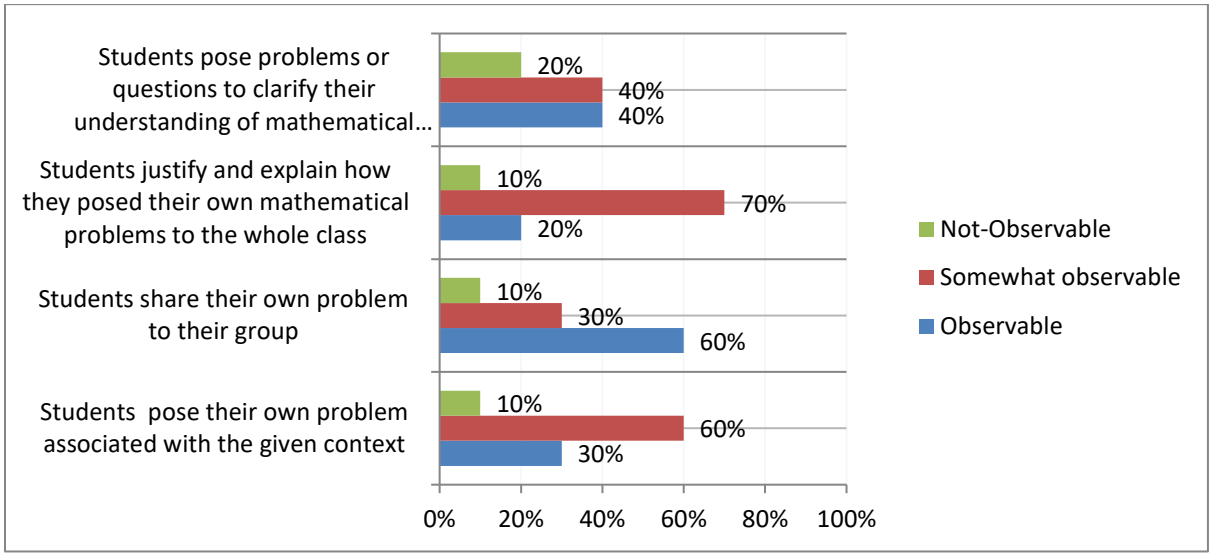


Figure 14: Students' context-based problem-posing classroom practices in learning data handling.

The lesson observation result (Figure 14) depicted that context-based problem-posing and solving instructional approaches have also positively influenced students' ability to share what they generated. 60% of the observed lessons demonstrated students' full practice in sharing their own problems with other students. Whereas, students' were struggling to justify and explain how they posed their own mathematical problems to the whole class.

3.4. Students' Interview Results

3.4.1. Students' thoughts and strategies to develop problem-posing skills at the beginning of the intervention

A wide variety of responses were provided by students when they were asked task-related questions. Reading the given information is the first strategy to pose their own problems (student codes: 6, 15, 33, 43, and 45) obtained when they were asked about what they did first to create the problem. Then, based on the student's response pattern, thinking about the problem and the solution of their problems (student codes: 6, 15, 43, and 45) is one of their thoughts and strategies utilized to pose their own problems. For instance, student code-15 considered creating a problem for further clarification of a concept that they had learned before. As a result, the student first considered posing a problem in the area that was challenging to find a solution. When asked, "What did you do first to create the problem?" Student Code-15 made an attempt to explain more in detail about the procedure to create a problem, as follows:

> *First, I looked at the prompts and the hint. After that, I had a problem with percentage because I didn't understand it when we were studying and I wanted to know. For example, the problem task that was given to students was the traditional foods they like, and I also created the students' favorite traditional dances (Ashenda, Shadey, Buhe, etc.) to know the percentage of the students. The problem I generated is as*

> *follows: A science teacher asked his 7th grade students about their favorite traditional dances. There are 12 who like Ashanda, 18 who like Shadai, and 8 who like Buhe dance. What is the percentage of students who like Shadai dance?*

Students posed their own mathematical problems by providing their own information associated with the given context (student codes: 6, 15, and 45) using Edir, favorite traditional foods and dances, and types of popular sports focused on the learning content percentage (student codes: 15, 43, and 45). For instance, when asked, "How did you develop this problem? Student Code-6 is clarified as:

> *Based on what was given, I thought to change it in another way. For example, to generate Problem 2, I was given an image of an Ethiopian coffee brewing ceremony and a dot graph showing the number of people who drank coffee. Based on what I have given, taking an Edir (a traditional form of social association whose members paid a fixed contribution monthly to help each other, mainly in bereavement or funerals) from the Ethiopian culture and giving information on the number of people who paid for an Edir every week, what I created is a problem that asks to know how many people paid for an Edir every week on average in a month. To find an average, you can divide the number of people who paid each week by the number of weeks*.

Student code 33 explained,

> *Based on what I have read here, I have created the problem, and I don't think it is good. My problem is: What are the traditional types of food in Ethiopia? And from what they prepared?*

When they were asked about the solvability of their problems, they responded that their problems are mathematically solvable (student codes: 6, 15, 43, and 45), whereas when they were asked, "Do you think that the problem you generated is based on the task given to generate the problem?" Student codes 6, 15, and 45 believed that they posed the problem based on the prompts. Student Code: 33 replied: I could have created a problem that involves the average of a given number, but I created a question based on my own choice. Student Code-43 said, "I created it based on the information given to me to find out what I did not understand."

In sum, reading the given information, making an attempt to pose a problem on a previously learned challenging topic for clarification, and providing their own information were students' ways of developing their problem-posing skills.

3.4.2. Students' thoughts and strategies to develop problem-posing skills in the middle of the intervention

Students were provided enormous ideas regarding their thoughts on developing their problem-posing skills. Students' attempts to pose their own problem were: 1) thinking about the mathematical knowledge with which they intended to address it; and 2) seeking to investigate the relationship between the learning contents. For instance, when asked, "Tell me about the problems

you created," student Code 6 discussed, "The problem I generated can be solved using addition, subtraction, and multiplication." Student's code 6 problem based on context-based problem-posing task 1 (cafeteria menu of some traditional Ethiopian foods (Beyaynetu, Shiro, Injera Firfir, coffee):

> *A school cafeteria offered 15 "beyaynetu" at the price of 35 birr, 9 "shiro" at the price of 25 birr, 3 pastas, and 3 macaroni at the same price. If the total income of the cafeteria is 990 birr, what is the cost of the pasta and macaroni?*

Whereas, regarding the problem-posing task 2, which focused on an image of an athletic path, student code-15 clarified why she posed the following problem: How many hours did athlete Haile Gebreslase take to complete 4 km? "I generated this problem by looking at the given image. I wanted to know how to calculate the relationship between kilometers and hours in an athletic race." 3) Reading the given prompts over and over again, getting ideas from their reading, and writing down the ideas that come to mind on paper (student codes 6, 15, 43, and 45). For instance, when asked, what did you do first to create the problem? Student code 6 replied, "The first thing I did was generate ideas by reading the given material over and over again, trying to understand it, then writing down the ideas that came to mind on paper." 4) Interpreting the given image, organizing data using tables and graphs, changing the values of the information, and converting it into mathematical question form. For instance, when asked, "How did you develop your problems? Student code-6 problem: How many minutes does athlete Haile Gebreslase take to run 1–6 km? Student Code 6 explained, "I generated it by looking at what is given in the picture and thinking about how many minutes it will take to complete 6 km in total." Student code-43 made an attempt to change the provided data on the cafeteria menu and organize it using a table as presented below. Student code-43 problem: Why is the price we pay for coffee and milk not explained in the table?

Collected information

list of foods	**Price (Birr)**	**Served food**	**Total sold price**
1. Beyaynetu	**38**	**20**	**760**
2. Shiro	**25**	**10**	**250**
3. Injera Firfir	**35**	**14**	**490**
4.Coffee	**10**	**-**	**-**
5. Milk	**15**	**-**	**-**

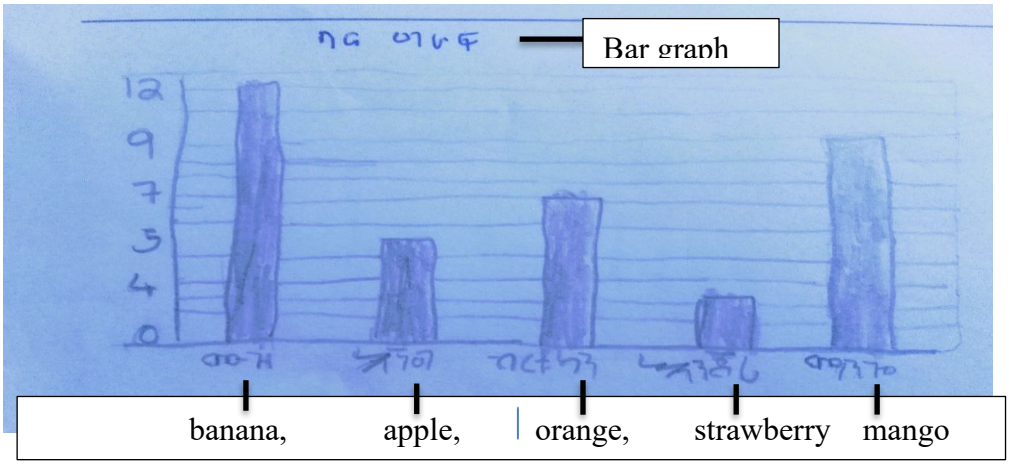
Student Code 45 responded, "I saw the problem-posing task first. After reading the given, I generated it by changing the value of the given menu."

In sum, students' thoughts for developing their problem-posing skills include thinking about the mathematical knowledge that their intended problems require them to address, reading the prompts repeatedly, interpreting the given image and picture, organizing data using tables, changing the values of the information, and converting it into mathematical question form.

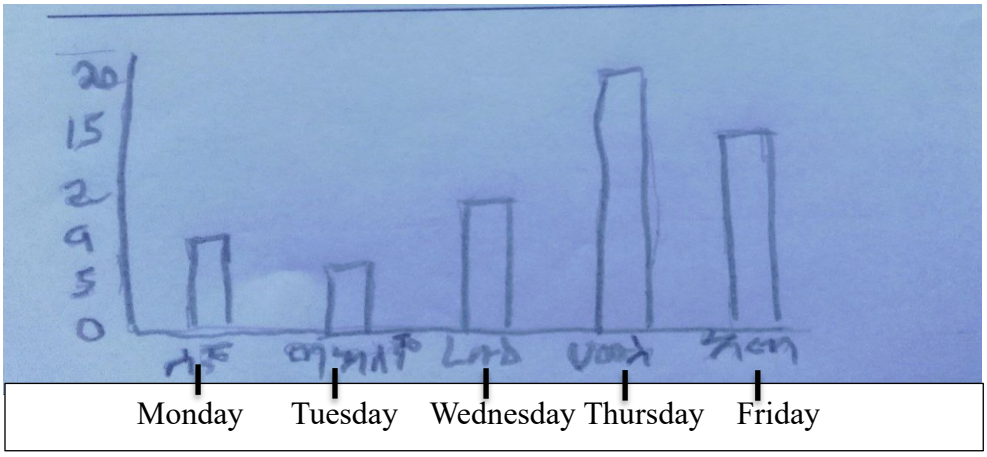
3.4.3 Students' thoughts and strategies to develop problem-posing skills at the End of the Intervention

A wide variety of students' responses were found when they were asked task-related questions at the end of the interventions. When asked, "Tell me about the problems you created?" Student code-6 explained, "I thought to create a problem by organizing the information given to us in a bar graph." My first problem is:

The types of fruits that students like are organized in the bar graph shown below.
What is the most popular type of fruit among students?



In the same way, I created Problem 2. First, after interpreting the image of Ethiopia's traditional coffee brewing image and the bar graph showing the number of people who drank coffee, I created my own problem as follows: In a school cafeteria, teachers had a morning breakfast with tea. Looking at the bar graph, on which day(s) did the cafe have more income from tea sales? A cup of tea is sold for 5 birr.



For example, given a bar graph, 9 cups of tea were sold on Monday, 5 cups on Tuesday, 12 cups on Wednesday, 21 cups on Thursday, and 15 cups on Friday. By multiplying the sum of each tea's daily sales by 5, it is possible to determine which day the cafeteria earns more.

Student code-15 explained: *first, I was thinking about the learning area that I should use for generating my problems. I used average numbers to pose my first problem so that I could understand the concept well, because most of the time I jumped numbers when I did average numbers. Problem 2: What is the total number of people who drank Abol, Tona, and Berka? In Ethiopian traditional coffee ceremonies, coffee is served three times, named abol (the first round of coffee), tona (the second round of coffee), and baraka (the third round of coffee). This can be solved by interpreting the image and bar graph, so it has a solution. Problem 3: Which team—men's or women's—will win out? These can be solved by comparing each group's total score. Or average mark. To make it more complex, what is the average score of the two groups? This can be solved by finding group averages. Problem 5: I tossed a coin five times and got two heads and three tails.*

If a coin is tossed 50 times in this experiment, what is the probability of getting a tail?

Student code 43 explained, *"Based on the given information, I organized the fruit types that students liked in a bar graph by looking at the images of fruits." Then, this was what I created: Problem 1: Based on that graph, what is the total number of students in the class?*

Next, problem 2: What is the total number of people who drank coffee? Regarding problem 3, we are given a detailed score of 5 boys and 5 girls out of 10. I also came up with the results for men and women and showed the average result, which I created as "What is the total sum of the men's team and the total sum of the women's team?" Thinking that problem 4 would have more depth, I decided to ask: whose group's average score is higher? Here's what I came up with for the problem that can be solved using the concept of experimental probability: I tossed a coin five times, and I got two tails (T) and three heads (H).

When a coin is tossed 10 times, how many tails (T) and how many heads (H) can come up? Student Code-45 explained, "*Regarding my first problem, the problem that I have generated is a problem that asks for their sum by taking the given starting point, changing into the same conditions, and changing the numbers."*

When asked, what did you do first to create the problem? they responded that reading and understanding the prompts was the first step they employed (student codes 6, 15, 33, and 43).

Student: Code 45 responded, "*To generate a problem, first, I thought of using the four mathematical operations."*

When asked, how did you develop your problems? An explanation of student code 33 is: For instance: *I generated, for example, the problem that involves average numbers by looking at the women's team table. Divide the result of the girls' group by 5. Then, to make it even more in-depth, which is the highest score from the men's and women's teams? I created the fourth problem by saying to find the largest average. I don't think I've come up with the fourth problem very well; it has little to do with the given prompt*. Student Code 45 response was: *I came up with the second problem based on comparison. For example, my problem was that there were people who drank coffee in my family. There are 11 people who drink Abol, 8 who drink Tona, and 5 who drink Bereka. How many more people drink Abol than those who drink Bereka? However, problems 3*

and 4 are sum-based problems. I didn't create according to the given instructions because I wanted to create differently and because I didn't see it well.

Students were asked about the solvability of their problems; they provided that they do believe that their problems can be solved mathematically. Whereas, when asked, "Do you think that the problem you generated is based on the task given to generate the problem?" based on their response, they believed that they posed based on the given task (student codes 6, 15, and 43).

In sum, students considered the given information as a starting point to generate their own problems. They made an attempt to create problems by organizing the information using bar graphs and tables, interpreting images and graphs, and creating their own story problem based on the prompts; creating problems based on specific learning domains by changing into the same conditions, interchanging the numbers, and reading and identifying the learning contents on which the problem focused. They made an attempt to pose comparison-word problems to make their own problems more complex.

4. Discussion

The study found that both the context-based problem-posing and solving instructional approaches group and the problem-posing and solving instructional approaches group significantly improved their problem-posing skills. The results of the present study disclosed that students who were taught data handling through context-based problem-posing and solving instructional approaches showed statistically significant progress from pre-test to post-test on total data handling PPS, context-type data handling PPS, and non-context-type data handling PPS with large, medium, and large effect sizes, respectively. The study's findings also revealed that students who were taught data handling through problem-posing and problem-solving approaches demonstrated statistically significant growth in terms of overall data handling PPS, context-type data handling PPS, and non-context-type data handling PPS with medium, medium, and large effect sizes, respectively, from the pre-test to the post-test. On the other hand, the comparison group demonstrated a statistically significant mean gain with small and medium effect sizes for total data handling PPS and non-context-type data handling PPS, respectively.

Related studies in the literature reveal that teaching mathematics through problem-posing approaches improves students' problem-posing skills (Divrik, 2023; Polat & Özkaya, 2023). Particularly, students who received problem-posing-based active learning activities showed that problem-posing pre- and post-test scores of the experimental group differed statistically significantly with a high level of effect size (Polat & Özkaya, 2023).

The qualitative results obtained from some interviewed students in the present study also supported the quantitative results. Students' thought of developing their problem-posing skills was: at the beginning of the intervention: reading, attempting to pose a problem on a previously learned challenging topics for clarification, and providing their own information; at the middle and end of

the intervention, thinking about the mathematical knowledge that their intended problems require them to address (for example, posing a problem to know the relationship between two learning contents), reading the prompts repeatedly, interpreting images and graphs and organizing data using tables, changing and interchanging the values of the information and converting it into mathematical question form, attempting to pose a problem that involves comparison for posing complex problems that possess more than one content and step, and posing problems that can be solved the concept of probability. They were also attempting to pose solvable, reasonable, creative, and complex problems. These implied that context-based problem-posing and solving instructional approaches are powerful student-centered approaches that build students' problem-posing skills. Using problem-posing approaches to complement mathematics instruction is a creative, student-centered, and emotionally engaging approach (Divrik, 2023). Besides, according to Wang (2021), problem-posing activities help students to think more, think deeper, ask more questions, and connect topics and content they learned about at school to everyday objects and real-life scenarios. The other major findings drawn from this study were that after statistically controlling the covariates (pre-test of total data handling PPS, context-type data handling PPS, and non-context-type data handling PPS) among the experimental and comparison groups, there were statistically significant differences in students' post-total data handling PPS, post-context-type data handling PPS, and post-non-context type data handling PPS among the groups. The variance of post-total data handling PPS, context-type data handling PPS, and non-context-type data handling PPS had each medium effect size. Particularly, the pairwise comparison result depicted that there were statistically significant differences in post-total data handling PPS and post-context-type data handling PPS with medium effect sizes between the context-based problem-posing and solving instructional approaches group and the comparison group. Besides, there were statistically significant differences in post-total data handling PPS, post-context type data handling PPS, and post-non-context type data handling PPS in learning data handling with medium effect sizes between the problem-posing and solving instructional approaches group and the comparison group. When we compared the two experimental groups, there was no statistically significant difference in problem-posing skills in learning data handling between the context-based problem-posing and solving instructional approaches group and the problem-posing and solving instructional approaches group.

Some empirical studies in the literature show that problem-posing interventions significantly improve the problem-posing skills of primary school students (Chen et al., 2015; Kopparla et al., 2019; Ozdemir & Sahal, 2018). Besides, both problem-posing and problem-solving interventions can enhance students' problem-posing skills (Bevan & Capraro, 2021; Bonotto & Santo, 2015; Kopparla et al., 2019; Martinez & Blanco, 2021). However, it seems no research has examined the potential benefits of context-based problem-posing and solving instruction approaches and problem-posing and solving instructional approaches to help students become more adept at posing context-type and non-context-type data handling problem tasks. In this study, however, when compared with the comparison group, both the context-based problem-posing and solving instructional approaches group and the problem-posing and solving instructional approaches group

significantly improved their problem-posing skills at a medium-level effect size on total data handling and context-type data handling aspects of problem-posing skills. Besides, context-based problem-posing and solving instructional approaches have also positively influenced students' ability to share what they generate; 60% of the observed lessons demonstrated students' full practice in sharing their own problems with other students. Whereas, 20% of observed lessons showed students' full practices in justifying and explaining how they posed their own mathematical problem to the whole class, and 40% of the observed lessons depicted posing their own problem to clarify their understanding.

The use of context-based problem-posing and solving instructional approaches in teaching data handling has shown a potential effect on students' problem-posing skills. Additionally, it motivates students to tackle their challenging content and see how various learning topics relate to one another in a given context. By using context-based approaches to problem-posing and solving, teachers may determine what students already know and do, what they would like to know and do, and what they don't know and do. These results implied that, in relation to the theoretical argument, context-based problem-posing and solving instructional approaches can connect what students can pose and solve alone using their already learned knowledge (zone of actual development (ZAD) and what students can pose and solve with the assistance of others (students' zone of proximal development (ZPD)).

5. Conclusion

Students have made significant progress from pre-test to post-test on their problem-posing skills on total data handling, context-type data handling, and non-context-type data handling problem-posing tasks with large, medium, and large levels of effect sizes through context-based problem-posing and solving instructional approaches. Besides, the study also found that after statistically controlling the covariates (pre-test of total-data handling PPS, context-type data handling PPS, and non-context-type data handling PPS) among the experimental and comparison groups, there were statistically significant differences in students' post-total data handling PPS, post-context-type data handling PPS, and post-non-context-type data handling PPS among the groups. To this end, a medium level of effect size has been observed on post-total data handling and post-context-type data handling aspects of problem-posing skills when the context-based problem-posing and solving instructional approaches group was compared to the comparison group. The qualitative results also depicted that diverse students thought of developing their problem-posing skills. Some of them include: thinking to pose a problem on previously learned challenging topics; providing their own information using Edir; favorite traditional foods; cultural dance; and types of popular sports; thinking about the mathematical knowledge that their intended problems require them to address, such as posing a problem to know the relationship between two learning contents; reading the given information repeatedly; interpreting images and graphs; and organizing data using tables;

changing and interchanging the values of the information; and attempting to pose a problem that involves comparison for posing complex problems. In sum, context-based problem-posing and solving instructional approaches are powerful student-centered approaches that build students' ability to generate new, solvable, reasonable, and complex mathematical problems.

6. Recommendations and Limitations

The problem-posing skills of students in learning data handling have been significantly improved by context-based problem-posing and solving instructional approaches. Hence, when developing teaching materials and methods of instruction to improve mathematics student learning, I advise curriculum designers and educational planners to take context-based problem-posing and solving instructional approaches into account.

This study is groundwork for Ethiopian students' mathematics learning and conducted with some limitations. The first limitation is that the role of parents in their students' problem-posing skills was not considered in this study. In context-based problem-posing and solving instructional approaches, students' problem-posing skills may also depend on their parents' characteristics and their support for their learning. In this regard, it is advisable to incorporate the role of parents for their problem-posing skills in future studies. A second limitation of this study is that the context-based problem-posing and solving instructional approaches group teacher was challenged to facilitate students' new problems according to the learning content, though the teacher has got training on context-based problem-posing and solving instructional approaches. Although problem-posing has not yet been included in the mathematics curriculum, and the teacher had no such experience before this study. Infusing problem-posing education into mathematics education and providing in-service and pre-service teacher training in the area of these instructional approaches may help them overcome the problem. A third limitation of this study is that it was limited to the learning domain of data handling. As a result, the period of intervention was short. A significant effect of the problem-posing skills pre-test on the post-test may be due to a short period of intervention, even though the covariates (pre-test) were controlled statistically. In light of this, besides using statistical control, a long period of intervention may eliminate or reduce the pre-test effect. Overall, it is recommended that context-based problem-posing and solving instructional materials should be prepared for future study, along with a prolonged duration of intervention.

Ethical statement: This study considered confidentiality, informed consent, avoidance of imposition, responsive communication, and classroom observation protocol as ethical issues to facilitate the study process. Informed consent including parental consent was obtained from all subjects involved in the study

Author contributions*:* This study was derived from the first author's dissertation under the principal advisor of the second author and the co-advisor of the third author. Each author has made

a significant contribution to the research paper and concurred with the findings and recommendations.

***Declaration of interest**:* No conflict of interest is declared by authors.

***Funding**:* No funding source is reported for this study.

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Appendix 1: Problem-posing skills evaluation rubrics

	Aspects of problem	0	1	2	3	4

	posing skills					
1	Solvability	The student made no apparent attempt to pose a problem.	The problem posed is not mathematical	The problem posed is mathematical but lacks more than one piece of information for solving	The problem posed is mathematical but is missing one piece of information for solving	The problem posed is mathematical and contains sufficient information for solving
2	Reasoning		The problem posed is completely unrelated to the prompt and not applicable in real life	The problem posed follows to some, but not all, of the constrains in the prompt.	The problem posed follows to all the constraints outlined in the prompt.	The problem posed follows the information given and applicable in real life.
3	Creativity		The problem only uses information directly provided in the prompt	The problem introduces new information, but it is not mathematically relevant.	The problem uses the existing information in a new way that is mathematically relevant.	The problem introduces new information mathematically necessary for solving the problem.
4	Complexity By steps		The problem posed does not require any math steps	The problem posed requires only a single math step	The problem posed requires two math steps	The problem posed requires three or more math steps.
5	Complexity by type		The problem posed no additional mathematical concepts	The problem posed consists one additional mathematical concepts	The problem posed consists two mathematical concept	The posed problem consists multiple mathematical concept

Article 11

Demystification of Quadratic Equation Using the Box Technique

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Abstract

Quadratic equations and expressions are important topics under school Algebra. Researchers have developed various methods of solving quadratic equations. These include: completing the square, formula, graphical and factorization methods. Students tend to have misconceptions about factorization and expansion. The Quadratic Equation Box (QEB) has been developed to enable students practically handle factorization of quadratic expressions. The use of Quadratic Equation Box will further enhance and retention and originality into the cognitive development of learners and will encourage them that even Algebra can be practically learnt.

Keywords: *Quadratic, Expressions, Equation, Box.*

1. Introduction

The pertinent virtue of mathematics as well as its contributions to the development of man and the whole world has made all to attach great importance to mathematics thereby making it compulsory at levels of education (Ugwuanyi, 2016). Everyone needs the basic concepts of mathematics to cope in this complex world. This is because the knowledge of mathematics helps individuals develop necessary skills for lifelong learning and effective functioning in the society. This important subject has suffered in the hands of many students and teachers as little attention is paid to how to demystify the teaching and learning of the concepts. Alio, Iyoke and Anaeche (2019) opined that demystification is the breaking down of complex process by using step-by-step explanation with a view to simplifying or elementarising the process of solving quadratic equation.

A quadratic equation (QE) is an algebraic equation of the second degree with one variable (Alio, Iyoke and Anaeche (2019). Ugwuanyi (2016) noted that a QE is an equation written in standard form as $ax^2 + bx + c = 0$ with $a \neq 0$, where a, b and c are constants and x is an unknown variable. Kabar (2018) posit that learners can solve QEs by using four identified methods namely: factorization, completing the square (CS), using the quadratic formula and graphical method.

Quadratic equations are a branch of mathematics that cut across all spheres and that need to be taught and learned in secondary schools (Alio, Iyoke and Anaeche 2019). Quadratic equations is a compulsory and important topic to be learned in secondary school mathematics as it bridges the gap between functions, polynomial derivatives, and linear equations.

In the course of teaching quadratic equation either by factorization, completing the square, or graph, students normally struggle to get the idea of what the teacher is trying to pass across to them. As a result of this problem, something positive must be done to save the teacher the mental torture in passing across knowledge to the students. Likewise, the students must be saved from mental agony of learning what appears to be meaningless to them. This calls for algebra manipulatives. Algebra manipulatives are concrete materials/models produced to aid the students understand abstract concepts in algebra (Ugwuanyi, 2016). Manipulatives support meaning-making and explicit teaching of links between different mathematical concepts. Some hands-on manipulatives that are typically used to model number concepts and processes are useful for extending the knowledge of algebra. Manipulatives help students understand and remember new concepts because they serve as analogies; the things manipulated are symbols for the new thing to be understood (Riener and Willingham, 2010; Marley and Carbonneau, 2015). Examples of algebra manipulatives are algebra tiles, algebra blocks and quadratic equation box to mention just a few.

The Quadratic Equation Box (QEB), can be improvised by making use of wood, plastic or synthetic as the case may be to produce relevant shapes like squares, rectangles and units that will enable a representation of the quadratic equations/expressions to be discussed. This can be used to simplify algebraic expressions, collecting like terms, expanding brackets, factorizing, and so on.

Activity 1:

Expansion of $(a + b)^2$, $(a - b)^2$ and $(a + b)(a - b)$.

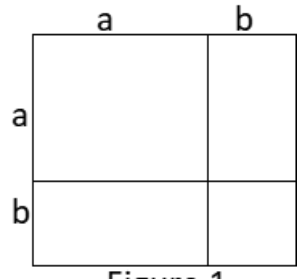


Figure 1

Activity 1:

a) $(a + b)^2$

i) Find the length and width of figure 1

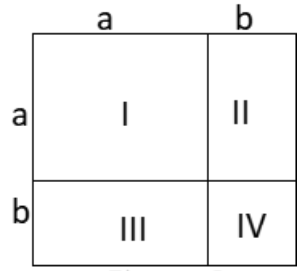


Figure 2

ii) Find the area of each part and the total area.

Expected answer:

$a^2 + 2ab + b^2$

(Please note the areas labelled I , II , III, and IV in Figure 2)

I = a x a= a^2
II = b x a= ab
III = a x b= ab
IV = b x b= b^2
∴ I + II + III + IV = $a^2 + ab + ab + b^2$
= $a^2 + 2ab + b^2$

Compare figures 1 and 2 what can you say about
$(a + b)^2$ and $(a^2 + 2ab + b^2)$?

Aim of Activity 1

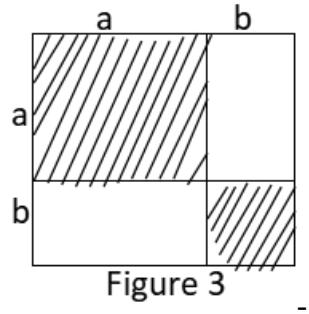
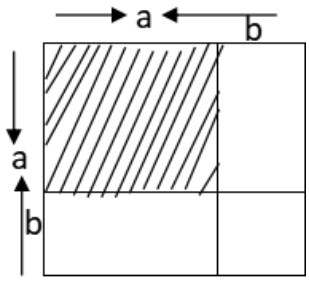


Figure 3

- Assists students to understand that $(a + b)^2 = a^2 + 2ab + b^2$ meaningfully and visually
- Clears misconception that $(a + b)^2 = a^2 + b^2$

Visually $a^2 + b^2$ is the shaded portion, whereas the whole segments give $(a + b)^2$

Activity 2: Expansion of $(a + b)^2$

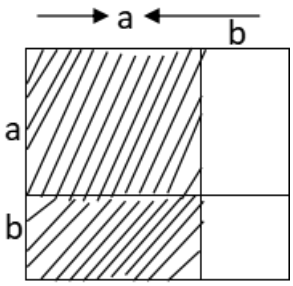


- Find the length and width of the shaded part

- Find the area of the square of side a
  - Find the area of the unshaded parts
  - Equate the two expressions obtained

Aim of Activity 2

- Let students understand the identity $(a + b)^2 = a^2 + 2ab + b^2$ meaningfully and visually.
- Clear misconception that $(a + b)^2 = a^2 + b^2$



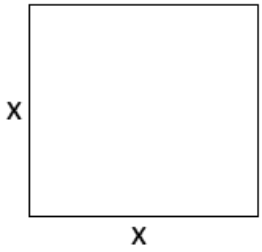
Activity 3: Expansion of $(a + b)(a - b)$

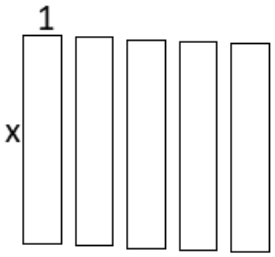
- Find the area of the shaded part
- Find the area of part C
- Find the total area of parts A and B by using the result of C obtained

Aim of Activity 3

- Let students understand the identity $(a + b)(a – b) = a^2 - b^2$ meaningfully and visually.

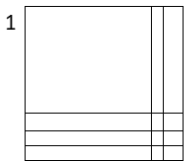
FACTORISATION OF QUADRATIC EQUATIONS (where Coefficient of $x^2 = 1$)





Activity 4:

- Given the pieces of squares and rectangles above, find the sum of the areas of these pieces.
- Make a rectangle by using the pieces of squares and rectangles above



2. ?

3. ?

- Find the area of the rectangle above, thus equating the result to the first exercise above:

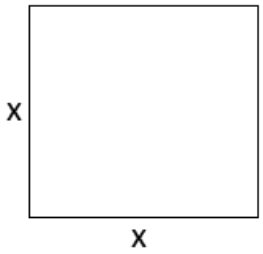
$X^2 + 5x + 6 = (x + 2)(x + 3)$

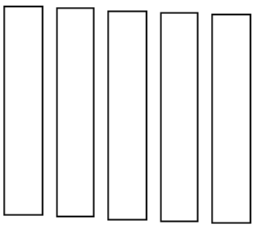
Aim of Activity 4

Let the students understand the relationship among coefficients of x and constant in a given quadratic expression.

Completing of the Squares

Activity 5

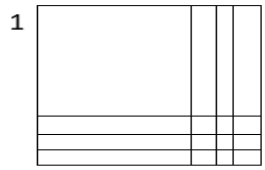


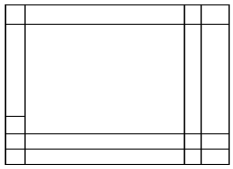


Given

- Find the sum of the areas of these pieces

- Make a square by using the pieces of squares and rectangles above.





3. ? etc

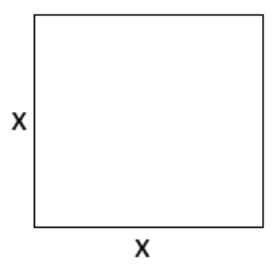
- Find the area of the squares made, thus equating the results to the expected answer above.

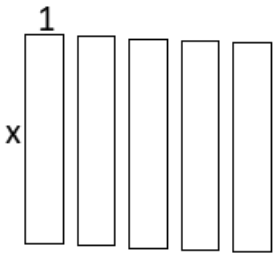
$X^2 + 6x + 9 = (X + 3)^2$

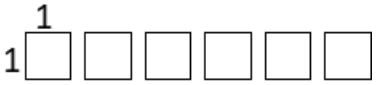
- Find the relationship connecting coefficient of x, constant terms and constant in the factorized form.

Activity 6

Given

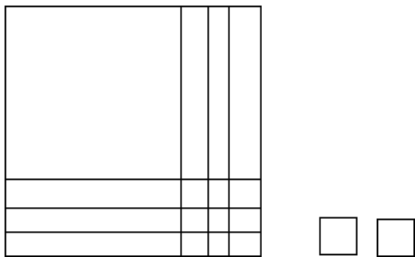






- Make a square by using all the pieces of rectangle and square.

- Factorise $x^2 + 6x + 11$ practically with the pieces



Hint

i.e $x^2 + 6x + 11 = (x + 3)^2 + 2$ (Discuss).

Exercise

Factorise the following quadratic expressions

i) $X^2 + 6x + 8$

ii) $x^2 + 9x + 20$

For years, students had difficulty expanding expressions leading to quadratic (especially with leading coefficient other than one) and factoring four-term polynomials traditionally done by the "factor by grouping" method). Quadratic Equation box has made both types of problems much easier (Lee, 1983; Waibochi, Ombati, 2004;Oluwaniyi, 2008) .The "box" is really just a multiplication table. Let us consider a simple example of 5x5 = 25. This can be expressed as (2 +3)(1 + 4).

$\therefore$ (2+3)(1+4) = 2 +3+8+12 = 25

X	2	3
1	2	3
4	8	12

In fact, we build up factoring first by using the box to multiply. For example, the multiplication of $(x + 2)(x + 3)$. Once the factors are set up, we find just find the product in each row and column and then add similar terms to get the final result (in this case, $x^2 + 5x + 6$).

X	x	3
x	x^2	$3x$
2	$2x$	6

$\therefore (x + 2)(x + 3) = x^2 + 3x + 2x + 6 = x^2 + 5x + 6$

To factorize $3x^2 + 11x + 6$, first we put $3x^2$ and 6 (i.e., the quadratic and constant terms) in the proper places inside the box (first row – first column and second-row second column respectively.

	$3x^2$	
		6

Fig 1a

	$3x^2$	$2x$
	$9x$	6

Fig 1b

X	$3x$	2

x	$3x^2$	$2x$
3	$9x$	6

Fig 1c

Then we look for the way to "split" the $11x$ into two terms such that their sum is $11x$ their product is $18x^2$ (i.e. the same as $3x^2$ times 6). In this case the correct choice is $9x$ and $2x$; those two terms are put in the remaining two boxes (b). Then we factor out the common factors in each row and each column. This procedure gives us the factorization of $(3x + 2)(x + 3)$, which is read from the left side and the top of the box (c).

We can check our answer by multiplying out using the same box. In the factoring of quadratic trinomials, we arrange the terms in decreasing degree. Additionally, if the quadratic term is negative, we factor the negative sign before using the box. In fact, any factor common to all three terms of the trinomial must be factored out before the box is used for the technique to work. Because of this consistency in setting up the problems, we can state the following rules for factoring out common factor in the "box". The common factors for the second row and second column will have the same sign as the first term in that row or column.

The last problem we want to demonstrate is that of four-term polynomial. Since when we "split" the middle term, we are really taking a trinomial and making it a four-term polynomial, we should also be able to use the QEB technique on the four-term polynomial.

Take the problem of factoring $2ax + 5by + bx + 10ay$.

We have four terms and four boxes. Since we are used to looking for common factors in each row and column, we want to place the terms with the least in common diagonally from each other.

	$2ax$	bx
	$10ay$	$5by$

Fig 2a

X	$2a$	b
x	$2ax$	bx
$5y$	$10ay$	$5by$

Fig 2b

We start by putting the first term of the polynomial in the first row-first column (in this case, 2ax) and the term that has the least in common with that term (in this case, 5by) in the second row-second column. The other two terms are then put in the remaining boxes (fig. 2(a)), and we factor

out the common factors just as we did before (fig. 2(b)). This process yields our factorization of ($x + 5y)(2a + b)$.

2. Conclusion

The use of Quadratic Equation Box (QEB) technique will enhance minds-on and hands-on experience in the process of factoring and expanding linear terms leading to quadratic equation. The box technique will greatly enhance factoring skills of students. This will make mathematics an enjoyable experience rather experience to be endured.

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Article 12

Exploring STEM Outreach Activities through Libraries: A Case Lusaka District Chapter

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Abstract

The paper explores the role of libraries in promoting Science, Technology, Engineering, and Mathematics (STEM) outreach activities in the Lusaka district of Zambia. Despite the increasing importance of STEM education, there is a persistent shortage of qualified STEM professionals in the country, which hinders economic growth and development. This study investigates the effectiveness of libraries in bridging this gap through STEM outreach activities, with a focus on the Lusaka district chapter. There is a lack of comprehensive understanding of the current state of STEM outreach activities in libraries in the Lusaka district, and how they can be improved to increase community engagement and STEM literacy. A mixed-methods approach was employed, combining surveys, interviews, and observations to gather data from 20 libraries and 30 stakeholders in the Lusaka district. The findings indicate that while libraries are offering some STEM-related activities, there is limited coordination and funding for these initiatives, which affects their quality and impact. The study highlights the importance of collaboration between libraries, schools, and community organizations to develop effective STEM outreach programs. The findings suggest that libraries can play a critical role in promoting STEM education and literacy if supported with adequate resources and coordination. Recommendations for improving STEM outreach activities in libraries include increasing funding, developing partnerships, and integrating technology-based initiatives.

Key Words: *STEM, Outreach, Activities, Libraries, Literacy*

1 Introduction

The global economy is increasingly driven by scientific innovation and technological advancement, making Science, Technology, Engineering, and Mathematics (STEM) education critical for national development. In Zambia, despite recognition of STEM's importance, there exists a significant gap between the demand for STEM professionals and the available qualified workforce. According to the Ministry of General Education (2019), Zambia produces fewer than 2,000 STEM graduates annually—a number insufficient to meet the nation's development needs. This shortage impedes progress toward achieving the Sustainable Development Goals and hampers economic diversification efforts in key sectors such as mining, agriculture, and technology.

Libraries, traditionally viewed as repositories of knowledge, have evolved into dynamic community hubs that facilitate learning beyond formal educational settings. Their potential to serve as platforms for STEM education remains largely untapped in many developing contexts, particularly in sub-Saharan Africa. In Zambia, where educational resources are limited and many children lack access to quality schooling, libraries offer alternative pathways to STEM literacy. The Lubuto Library Project demonstrates this potential through its innovative programming that reaches vulnerable children and youth who are excluded from formal education systems.

This paper focuses specifically on Lusaka District, Zambia's capital and largest urban centre, where libraries have the potential to reach diverse populations but face unique challenges related to urbanization, poverty, and educational inequality. The study investigates how libraries in Lusaka are currently engaging in STEM outreach, what challenges they face, and how their efforts might be enhanced to better serve community needs. By examining these questions, this research contributes to broader discussions about educational innovation and community-based learning in resource-constrained environments.

2 Literature Review

2.1 The Global Context of STEM Education

STEM education has become a priority area for investment worldwide due to its recognized importance in driving innovation, economic growth, and sustainable development. According to the World Bank (2023), countries that have invested strategically in STEM education have experienced significant returns in terms of technological adoption, productivity growth, and global competitiveness. In Africa, STEM education is particularly crucial for addressing continental challenges such as food security, healthcare access, and infrastructure development. The African Union's Agenda 2063 emphasizes STEM as essential for transforming African economies and achieving self-reliance.

2.2 STEM Education in Zambia: Challenges and Opportunities

Zambia faces multiple challenges in STEM education, including inadequate funding, insufficient qualified teachers, limited teaching materials, and poor infrastructure. The EFA Global Monitoring Report (2014) noted that in Zambia, 91% of children aged 7-8 cannot read a word in their language of instruction, indicating fundamental literacy challenges that undermine STEM learning. There is only one mathematics textbook for every 3.5 second-graders, creating significant resource constraints for foundational STEM education.

Despite these challenges, Zambia has made efforts to prioritize STEM education through curriculum reforms and strategic initiatives. The Competence-Based Curriculum introduced by the Ministry of Education emphasizes practical skills and problem-solving abilities relevant to STEM

fields. Additionally, partnerships with international organizations such as the Japan International Cooperation Agency (JICA) have supported STEM capacity building, as evidenced by the Knowledge Co-Creation Programme for Africa that concluded in Lusaka with a focus on accelerating STEM learning competence.

2.3 Libraries as Educational Platforms

Libraries have evolved from passive repositories of books to active learning spaces that facilitate knowledge creation and community engagement. Internationally, libraries have successfully implemented STEM programs that complement formal education systems. The Lubuto Library Project in Zambia exemplifies this approach, providing open-access libraries with carefully crafted book collections and holistic educational, cultural, and community programs. Their model demonstrates how libraries can serve as effective platforms for STEM education, particularly for vulnerable populations who might otherwise be excluded.

Table 1: Typology of Library-Based STEM Activities

Activity Type	Description	Examples from Zambia
Technology Access	Providing computers and digital resources	Lubuto's access to OLPC XO laptops and educational tablets
Structured Programs	Organized workshops and classes	Coding workshops for girls supported by Motorola Solutions Foundation
STEM Collections	Curated physical and digital resources	STEM study hubs established in Kasama
Community Partnerships	Collaborative programs with organizations	Partnership with Zambia Library Service and Book Aid International

2.4 Gap in Literature

While there is growing recognition of libraries' potential in STEM education, few studies have specifically examined their role in the Zambian context, particularly in urban settings like Lusaka. Munyinda's (2020) research on public libraries in Zambia provides a foundation but does not focus specifically on STEM outreach in urban districts. This study aims to address this gap by providing empirical evidence on the current state of STEM outreach activities in Lusaka's libraries and offering recommendations for enhancement.

3 Methodology

3.1 Research Design

This study employed a mixed-methods approach to gather comprehensive data on STEM outreach activities in Lusaka's libraries. The combination of quantitative and qualitative methods allowed for triangulation of data, providing a more complete understanding of the phenomenon under study. The research was conducted over a six-month period from January to June 2025, with data collection occurring in phases to allow for iterative analysis and refinement of research instruments.

3.2 Sampling and Participants

The study included 20 libraries across Lusaka District, selected through stratified random sampling to ensure representation of different library types (public, community, school, and special libraries). From these libraries, 30 stakeholders were purposively selected for in-depth interviews, including librarians, educators, community leaders, and representatives from organizations involved in STEM education. The sample size was determined based on saturation principles, where data collection continued until no new themes emerged.

Table 2: Research Participants and Data Collection Methods

Participant Category	Number	Data Collection Method	Focus of Inquiry
Library Managers	15	Surveys and interviews	STEM programs, funding, challenges
Library Staff	25	Surveys	Daily activities, training needs
Educators	10	Interviews	School-library partnerships
Community Representatives	5	Interviews	Community needs and engagement
Government Officials	3	Interviews	Policy perspectives
Students	40	Observations	Participation in STEM activities

3.3 Data Collection Methods

Surveys: Quantitative data was collected through structured surveys administered to library managers and staff. The surveys gathered information on the types of STEM activities offered, frequency of programs, participation rates, funding sources, and staff capacity. The survey instrument was pre-tested with three libraries not included in the study sample to ensure clarity and validity.

Interviews: Semi-structured interviews were conducted with stakeholders to gather qualitative insights on perceptions, challenges, and opportunities related to library-based STEM outreach.

Interview guides were developed based on preliminary survey findings and were adapted as new themes emerged. Interviews were recorded with permission and transcribed verbatim for analysis.

Observations: Site visits to libraries allowed for direct observation of STEM activities in natural settings. Observation protocols focused on participant engagement, resource utilization, teaching methodologies, and overall program implementation. Observations were particularly valuable for understanding the practical challenges and success factors that might not be revealed through surveys or interviews.

3.4 Data Analysis

Quantitative data from surveys was analyzed using descriptive statistics to identify patterns and trends in STEM outreach activities. Qualitative data from interviews and observations was analyzed through thematic analysis using NVivo software. The analysis followed an iterative process of coding, category development, and theme identification. Methodological triangulation strengthened the validity of findings by combining different data sources and analysis techniques.

3.5 Ethical Considerations

The study received ethical approval from the University of Zambia's Research Ethics Committee. All participants provided informed consent after receiving clear information about the study's purpose and their rights. Confidentiality was maintained through anonymization of data and secure storage of information. The research adhered to principles of cultural sensitivity and respect for local contexts throughout the data collection process.

4 Findings

4.1 Survey Results: STEM Activities in Lusaka Libraries

The survey revealed that 35% of libraries (7 out of 20) reported having structured STEM programs, while an additional 45% (9 out of 20) occasionally offered STEM-related activities. The remaining 20% (4 out of 20) had no specific STEM programming but expressed interest in developing such initiatives. Libraries with structured STEM programs tended to be those with established partnerships with organizations like the Lubuto Library Project or the Zambia Library Service.

The types of STEM activities offered varied significantly, with workshops being the most common (70%), followed by science fairs (25%) and coding clubs (10%). Most libraries (85%) reported that their STEM activities primarily targeted children and youth aged 10-24, with limited programming for adults or younger children. The average participation per STEM event was approximately 50 people, though this varied widely depending on the type of activity and library location.

Funding emerged as a critical constraint for STEM activities. Sixty percent of libraries reported relying on community donations for their STEM programs, while only 15% received government grants specifically for STEM initiatives. The remaining libraries used general operating budgets

(20%) or had no dedicated funding for STEM (5%). Libraries with external funding sources, such as the Lubuto Libraries supported by the Motorola Solutions Foundation, were able to offer more sustained and high-quality programming.

4.2 Interview Results: Stakeholder Perspectives

Stakeholders unanimously recognized the potential value of libraries in promoting STEM education but highlighted several challenges limiting their effectiveness. The most frequently cited challenge was insufficient funding (83% of interviewees), which affected the ability to acquire resources, train staff, and sustain programs. As one librarian explained: "We have many ideas for STEM activities, but without adequate funding, we can only do so much. We often have to choose between buying books or running programs."

Another significant challenge was the lack of coordination between libraries, schools, and community organizations. Eighty percent of stakeholders indicated that better collaboration would enhance the impact of STEM outreach efforts. An education officer noted: "Libraries, schools, and NGOs often work in isolation. If we could coordinate our efforts, we could create a more comprehensive STEM ecosystem that benefits all learners."

The limited training available for library staff in STEM-related areas was another constraint, mentioned by 70% of interviewees. Most library staff had backgrounds in humanities or general librarianship rather than STEM fields, making it challenging to develop and implement effective STEM programs. Some libraries addressed this through partnerships with organizations that provided training, such as the Zambia Library Service's program to strengthen librarians' skills in supporting students' research on STEM subjects.

Despite these challenges, stakeholders identified several success factors for library-based STEM outreach. These included community involvement, practical hands-on activities, integration of technology, and alignment with local needs and interests. The Lubuto Library Project's approach of combining technology access with culturally relevant programming was cited as a particularly effective model.

4.3 Observation Results: Program Implementation

Observations of STEM activities in libraries revealed significant variation in program quality and participant engagement. Libraries with dedicated spaces and resources for STEM, such as the Lubuto Libraries with their purpose-built facilities and access to technology, demonstrated higher levels of participant engagement and more sophisticated programming. These libraries offered a range of activities including coding workshops, digital literacy training, and access to educational technology.

Programs that incorporated hands-on activities and real-world applications tended to generate more interest and sustained participation. For example, coding workshops where girls built and programmed computers were particularly successful, with participants showing enthusiasm for "bringing them to life". In contrast, programs that relied primarily on lectures or theoretical approaches had lower engagement levels.

Observations also revealed gender disparities in participation, particularly in technology-focused activities. Libraries that implemented targeted initiatives for girls, such as the STEM study hubs specifically designed to encourage female learners, were more successful in achieving gender balance in their STEM programs.

5 Discussion

5.1 Key Themes

The findings of this study reveal several interconnected themes regarding library-based STEM outreach in Lusaka District. First, there is a clear mismatch between potential and reality regarding libraries' role in STEM education. While libraries have the physical space, community trust, and institutional framework to serve as effective STEM hubs, most lack the resources and capacity to fulfil this potential. This aligns with Munyinda's (2020) findings about the underutilization of public libraries in Zambia for educational purposes.

Second, the funding constraint emerges as a critical barrier that affects all aspects of STEM programming. Without dedicated funding, libraries cannot acquire specialized resources, train staff, or develop sustained programs. This creates a vicious cycle where limited programs lead to limited demonstrated impact, which in turn makes it difficult to secure funding. The experiences of libraries that have successfully attracted external funding, such as those partnering with the Lubuto Library Project or Book Aid International, demonstrate how adequate resources can transform library-based STEM initiatives.

Third, the coordination gap between libraries and other educational institutions represents a missed opportunity for creating a cohesive STEM learning ecosystem. As noted by stakeholders, better collaboration between libraries, schools, and community organizations could leverage complementary strengths and resources. The partnership between TEVETA, Zambia Federation of Employers, and the National STEM Foundation to enhance skills training and integrate STEM into vocational education offers a promising model for multi-stakeholder collaboration that could be adapted for library contexts.

5.2 Implications for Practice

The findings suggest several practical implications for enhancing library-based STEM outreach in Lusaka. First, libraries should prioritize developing strategic partnerships with organizations that can provide resources, expertise, and funding for STEM programs. The success of partnerships

such as that between the Zambia Library Service and Book Aid International in establishing STEM study hubs demonstrates the value of such collaborations.

Second, there is a need for contextually appropriate STEM programming that reflects local needs and resources. The Lubuto Library Project's approach of integrating Zambian languages and cultural elements into their literacy programs offers a model for how STEM education can be locally relevant while still maintaining global standards. Libraries should develop STEM activities that connect to everyday experiences and practical applications, particularly in areas such as agriculture, health, and technology that are relevant to Zambia's development goals.

Third, technology integration emerges as both a challenge and an opportunity. While many libraries lack adequate technological resources, those that have embraced technology, such as through providing computer access or coding workshops, have seen increased engagement, particularly among youth. The Lubuto Library Project's success in advocating for free Internet in public libraries demonstrates how strategic advocacy can address resource constraints.

5.3 Limitations and Future Research

This study has several limitations that suggest directions for future research. First, the focus on Lusaka District limits the generalizability of findings to rural areas, which may face different challenges and opportunities. Future research should examine library-based STEM outreach in rural contexts, where educational resources are often even more limited.

Second, the study focused primarily on library perspectives rather than participant outcomes. Future research should investigate the long-term impact of library-based STEM programs on educational and career pathways, particularly for underrepresented groups such as girls and vulnerable youth.

Third, the study was conducted at a single point in time, capturing a snapshot of STEM activities rather than their evolution over time. Longitudinal research would provide valuable insights into how library-based STEM initiatives develop and sustain themselves, and what factors contribute to their long-term success or failure.

6 Recommendations

Based on the findings of this study, the following recommendations are proposed for enhancing library-based STEM outreach in Lusaka District:

6.1 Strategic Funding Development

Libraries should pursue diverse funding sources to support STEM initiatives, including government grants, private sector partnerships, international development funding, and community fundraising. Specifically:

The Zambian government should establish a dedicated funding stream for library STEM programs through the Ministry of Technology and Science and the Ministry of Education.

Libraries should develop proposals for international STEM education initiatives, building on successful models like the Motorola Solutions Foundation grant that supported coding workshops for girls.

Private sector companies with interests in STEM fields should be engaged as corporate sponsors for library programs, creating mutually beneficial partnerships that develop future talent while fulfilling corporate social responsibility objectives.

6.2 Partnership Development

Libraries should formalize partnerships with educational institutions, community organizations, and government agencies to create a coordinated STEM ecosystem. Specifically:

- Libraries should develop memoranda of understanding with schools to define roles and responsibilities in STEM education, facilitating regular communication and collaboration.
- Partnerships with organizations like the Lubuto Library Project should be expanded to leverage their expertise in developing comprehensive STEM programming.
- Libraries should engage with industry associations such as the Zambia Federation of Employers to ensure STEM programs align with workforce needs.

6.3 Technology Integration

Libraries should embrace technology as a key enabler of STEM education while addressing access disparities. Specifically:

- Libraries should prioritize providing free Internet access and computer facilities, following the Lubuto Library Project's successful advocacy model.
- Digital literacy should be integrated into all STEM programming, recognizing that technology skills are fundamental to STEM learning.
- Libraries should develop maker spaces with adaptable technologies that meet a range of needs, from basic digital literacy to advanced coding and robotics.

6.4 Capacity Building

Investment in staff training is essential for developing and sustaining quality STEM programs. Specifically:

- Library staff should receive regular professional development in STEM education methodologies, digital literacy, and program evaluation.

- Training programs should be developed in collaboration with library science programs at institutions like the University of Zambia to ensure sustainability.
- Libraries should create opportunities for staff exchange and learning visits to successful STEM programs, both within Zambia and internationally.

6.5 Inclusive Programming

Library STEM programs should specifically address participation gaps for underrepresented groups. Specifically:

- Libraries should develop targeted programs for girls and young women, building on successful models like the STEM study hubs designed to encourage female learners.
- Programs should be designed to be accessible to vulnerable populations, including children living in poverty, those with disabilities, and out-of-school youth.
- STEM activities should incorporate Zambian cultural elements and local knowledge to ensure relevance and respect for indigenous ways of knowing.

Table 3: Framework for Enhancing Library-Based STEM Outreach in Lusaka

Strategic Area	Current Status	Desired Future State	Key Actions
Funding	Reliance on donations; limited dedicated funding	Diverse, sustainable funding sources	Develop grant-writing capacity; pursue public-private partnerships
Partnerships	Ad hoc collaborations; limited coordination	Formal, strategic partnerships with clear roles	Create partnership frameworks; establish regular coordination mechanisms
Technology	Limited access; digital divide	Technology-integrated programs with equitable access	Advocate for free Internet; develop maker spaces; provide digital literacy
Capacity	Limited STEM training for staff	Continuous professional development in STEM education	Establish training programs; create communities of practice
Inclusion	Participation gaps for girls and vulnerable groups	Equitable participation across all demographic groups	Develop targeted programs; remove barriers to participation

7. Conclusion

This study has demonstrated that libraries in Lusaka District have significant potential to serve as vital platforms for STEM education, particularly for populations who might otherwise lack access to quality STEM learning opportunities. However, this potential remains largely untapped due to resource constraints, coordination gaps, and capacity limitations. The findings suggest that with strategic investment, partnership development, and capacity building, libraries could play a much more significant role in addressing Zambia's STEM workforce shortage.

The experiences of successful initiatives like the Lubuto Library Project and the Zambia Library Service's STEM hubs provide proof of concept for what is possible when libraries are adequately supported to develop comprehensive STEM programming. These models demonstrate how libraries can combine technology access, culturally relevant content, and community engagement to create impactful STEM learning experiences.

As Zambia continues to prioritize STEM education as a driver of national development, libraries deserve recognition as strategic assets that can complement formal education systems and extend STEM learning to diverse populations. By implementing the recommendations outlined in this study, policymakers, library administrators, and community stakeholders can work together to unlock the transformative potential of library-based STEM outreach in Lusaka and beyond.

The future of library-based STEM education in Zambia will depend on the ability of various stakeholders to collaborate effectively, leverage resources, and adapt innovatively to changing educational needs and technological possibilities. With the right support and vision, libraries can become vibrant STEM hubs that contribute significantly to developing the next generation of Zambian scientists, technologists, engineers, and mathematicians.

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Article 13

STEM Outreach Programs: Evaluating the Impact on Rural and Low-Income Communities

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Abstract

This study investigates the role of AI-driven personalized learning systems in advancing gender equity within STEM education. Employing a mixed-methods research design, the study examines how AI tools can enhance student engagement and address gender disparities by providing individualized learning experiences. The quantitative analysis shows a significant increase in engagement and motivation among female students exposed to AI-driven interventions compared to traditional educational methods. Qualitative feedback further highlights that AI systems are effective in identifying and addressing individual learning needs, which contributes to more equitable educational outcomes. However, the research also reveals that while AI can mitigate some barriers faced by female students, it is not a standalone solution. Persistent structural and cultural challenges continue to influence gender imbalances in STEM fields. Therefore, while AI tools offer promising enhancements to personalized learning, their effectiveness is contingent upon their integration with broader educational reforms and systemic changes. The findings suggest that combining AI technology with other gender-equity initiatives can lead to more comprehensive improvements in STEM education. This study underscores the need for further research into the development of inclusive AI models, the exploration of AI's long-term effects on career trajectories, and the integration of AI with additional educational practices. By addressing these areas, future research can provide deeper insights into how AI can be leveraged to promote gender equity and improve educational outcomes.

Keywords: AI-driven learning, gender equity, STEM education, personalized learning, educational technology.

1. Introduction to the Study

In recent years, STEM outreach programs have gained prominence as a strategic effort to bridge educational gaps and foster greater participation in science, technology, engineering, and mathematics among underrepresented groups. Despite these efforts, there remains a significant disparity in STEM engagement between urban and rural, as well as between affluent and low-income communities. This study aims to evaluate the effectiveness of these outreach programs

specifically within rural and low-income areas, focusing on their ability to inspire and support sustained interest and participation in STEM fields.

The increasing importance of STEM skills in today's job market underscores the need for equitable educational opportunities across all communities. By examining the impact of outreach initiatives designed to promote STEM careers and education in these underserved areas, this research seeks to identify successful strategies and potential areas for improvement. The findings from this study could offer valuable insights for policymakers, educators, and program developers striving to enhance STEM access and engagement in rural and low-income populations.

1.1 Background to the Study

Rural and low-income communities have historically faced numerous challenges in accessing quality educational resources and opportunities, particularly in STEM disciplines. Geographic isolation, limited funding, and fewer educational resources contribute to these challenges, often resulting in lower participation rates and diminished interest in STEM fields among students in these areas. STEM outreach programs have emerged as a vital tool in addressing these disparities by providing targeted support and resources aimed at increasing student engagement and achievement in these critical areas.

Several outreach programs have been implemented across various regions, ranging from after-school clubs to summer camps and online resources. While some programs have demonstrated success in fostering STEM interest and skills among participants, there is a need for a comprehensive evaluation of their effectiveness specifically in rural and low-income contexts. Understanding the unique barriers and opportunities in these communities is crucial for tailoring outreach efforts to maximize their impact and ensure that all students have the chance to succeed in STEM careers.

This study will explore the current landscape of STEM outreach programs, assessing their reach, effectiveness, and sustainability in rural and low-income areas. By analyzing both qualitative and quantitative data, the research will aim to provide a clearer picture of how these programs can be optimized to better serve disadvantaged communities and address the broader issue of educational equity in STEM fields.

1.2 Hypothesis

STEM outreach programs are effective in increasing participation and interest in STEM fields among students in rural and low-income communities, but their impact varies significantly based on program design, resource availability, and community engagement.

1.3 Purpose of the Study

The purpose of this study is to evaluate the effectiveness of STEM outreach programs in rural and

low-income communities by assessing their impact on student engagement, interest, and participation in STEM fields. The study aims to identify key factors contributing to the success or limitations of these programs and provide recommendations for enhancing their effectiveness and sustainability.

1.4 Scope of the Study

This study will focus on STEM outreach programs implemented in rural and low-income communities within [specific region/country]. It will examine a range of programs, including after-school initiatives, summer camps, and online resources, and will use both qualitative and quantitative methods to assess their impact. The study will not cover urban or high-income areas or delve into broader educational issues outside the realm of STEM outreach.

1.5 Limitations

The study may face limitations related to the availability and quality of data, as well as the variability in program implementation and community contexts. Limited access to comprehensive program evaluations and differing definitions of success across programs may impact the consistency of findings. Additionally, the study's focus on specific regions or types of programs may limit the generalizability of the results to other contexts or broader populations.

2: Literature Review

2.1. Historical Context of STEM Education Disparities

The disparities in STEM education between rural and urban, as well as affluent and low-income communities, have deep roots in the historical development of educational systems. Historically, rural and low-income areas have faced systemic challenges such as limited funding, fewer qualified teachers, and inadequate infrastructure. These factors have contributed to a persistent gap in STEM education quality and student outcomes compared to their urban and wealthier counterparts (Beineke, 2015; Borman & Dowling, 2008).

Research has shown that students in these underserved communities often have lower access to advanced coursework and extracurricular opportunities, which are crucial for developing interest and skills in STEM fields (Barton & Tan, 2010). The lack of resources and exposure to STEM careers early on can hinder the development of necessary skills and reduce the likelihood of pursuing STEM-related higher education or careers (National Research Council, 2013).

Efforts to address these disparities have been varied, including federal and state-level interventions, but progress has been slow. For example, initiatives such as the No Child Left behind Act aimed to address educational inequities but faced criticism for inadequate implementation and insufficient focus on STEM (Lee & Wexler, 2008). Understanding this historical context is crucial for evaluating current outreach programs and their effectiveness.

Current research indicates that despite ongoing efforts, significant gaps remain in STEM engagement and achievement. This historical perspective provides a foundation for assessing how outreach programs can better address these entrenched disparities and improve outcomes for students in rural and low-income communities (Murray & Sorrell, 2021).

2.2. Current STEM Outreach Programs and Their Models

STEM outreach programs come in various models, including after-school programs, summer camps, and online resources. These programs aim to increase student engagement and interest in STEM through hands-on activities, mentoring, and exposure to STEM careers (Bevan et al., 2014). Each model has its strengths and challenges, and their effectiveness can vary based on implementation and local context.

After-school programs often provide additional STEM learning opportunities in a less formal setting, which can be beneficial for reinforcing classroom instruction and fostering interest (Durlak et al., 2011). However, these programs may face challenges related to funding, staff training, and maintaining student engagement outside of regular school hours (Posner & Vandell, 1999).

Summer camps offer immersive STEM experiences and can help students develop deeper interests and skills in a concentrated period (Barton et al., 2013). Yet, they may be limited by accessibility issues, as transportation and costs can be barriers for students from low-income families (Schroeder et al., 2018).

Online resources provide scalable solutions for reaching a broader audience and can offer flexible learning opportunities (Yuan et al., 2013). However, these resources may lack the interactive and social elements that are crucial for effective learning and engagement (Chen et al., 2021). Evaluating these different models helps identify which approaches are most effective in rural and low-income settings.

2.3. Impact of STEM Outreach on Student Engagement

Student engagement is a key factor in the effectiveness of STEM outreach programs. Research has shown that high levels of engagement are associated with increased interest in STEM fields and higher academic achievement (Fredricks et al., 2004). Outreach programs that successfully engage students through interactive and relevant content tend to have better outcomes.

Programs that incorporate real-world applications of STEM concepts and offer opportunities for hands-on learning tend to see higher levels of student engagement (Hofstein & Rosenfeld, 1996). Engaging students in projects that are connected to their own experiences and interests can foster a deeper connection to STEM subjects (Brophy et al., 2008).

Mentoring and role models also play a significant role in student engagement. Exposure to professionals in STEM fields can inspire students and provide valuable insights into potential career paths (Zeldin et al., 2008). However, the effectiveness of mentoring programs can vary based on the quality of mentorship and the alignment of role models with students' backgrounds (O'Brien & Moss, 2018).

Understanding how different aspects of outreach programs contribute to student engagement is crucial for designing effective initiatives. Identifying best practices and potential areas for improvement can help enhance the impact of these programs on students in rural and low-income communities.

2.4. Challenges Faced by Rural and Low-Income Communities

Rural and low-income communities face unique challenges that can impact the effectiveness of STEM outreach programs. Geographic isolation can limit access to quality educational resources and extracurricular opportunities (McLaughlin & Pfeiffer, 2002). This isolation can make it difficult for students to participate in programs and events that are crucial for developing STEM skills.

Funding limitations are another significant challenge. Schools and communities with limited budgets may struggle to provide adequate STEM resources, support, and infrastructure (Kober, 2005). Outreach programs in these areas often face constraints related to funding, which can affect their ability to deliver high-quality and sustained support.

Additionally, socio-economic factors such as family support, access to technology, and awareness of STEM careers can influence student participation and success in STEM programs (Jordan et al., 2009). Addressing these challenges requires targeted strategies that consider the specific needs and barriers faced by students in rural and low-income settings.

Recognizing and addressing these challenges is essential for developing effective STEM outreach programs. Tailoring interventions to meet the needs of these communities can help overcome barriers and improve educational outcomes.

2.5. Evaluation Methods for STEM Outreach Programs

Evaluating the effectiveness of STEM outreach programs involves using various research methods to assess their impact on student outcomes. Common evaluation methods include quantitative measures such as test scores and participation rates, as well as qualitative assessments such as surveys and interviews (Creswell, 2014).

Quantitative methods can provide insights into the measurable effects of outreach programs on student achievement and engagement. For example, pre- and post-program assessments can help determine whether students have gained new skills or increased their interest in STEM fields

(Wang et al., 2019).

Qualitative methods offer a deeper understanding of student experiences and perceptions. Surveys and interviews can capture students' attitudes towards STEM, their experiences with the program, and any barriers they may have encountered (Patton, 2008). Combining these methods provides a comprehensive evaluation of program effectiveness.

Effective evaluation also requires considering contextual factors that may influence outcomes, such as community support and program implementation quality. Developing robust evaluation frameworks and tools is crucial for accurately assessing the impact of STEM outreach programs and informing improvements.

2.6. Research Gaps and Future Directions

Despite the growth of STEM outreach programs, there are significant research gaps that need addressing. Current studies often lack comprehensive evaluations of program effectiveness in rural and low-income settings, and there is a need for more targeted research on how different program models perform in these contexts (Friedman & Smith, 2020).

There is also a need for more research on the long-term impacts of STEM outreach programs. While many studies focus on short-term outcomes, understanding the sustained effects on student career choices and academic achievement is crucial (DeWitt & Osbourne, 2014). Longitudinal studies can provide insights into how early STEM engagement influences later educational and career trajectories.

Additionally, research on the integration of technology in STEM outreach programs is limited. Exploring how digital tools and online platforms can be effectively utilized in rural and low-income settings could offer new opportunities for enhancing program reach and impact (Hoffmann et al., 2021).

Addressing these research gaps can help refine STEM outreach programs and contribute to more equitable educational opportunities. Future studies should aim to fill these gaps and provide actionable recommendations for improving outreach efforts in underserved communities.

3. Methodology

3.1. Research Design

This study employed a mixed-methods research design, combining both quantitative and qualitative approaches to provide a comprehensive evaluation of STEM outreach programs in rural and low-income communities. This approach allowed for the collection of diverse types of data

and a more nuanced understanding of the effectiveness and impact of these programs. The research design included three main components: a survey of program participants, case studies of selected programs, and interviews with key stakeholders.

3.2. Quantitative Methods

3.2.1. Survey Design and Implementation

A structured survey was developed to assess the impact of STEM outreach programs on student engagement, interest, and participation. The survey was distributed to students who participated in various STEM outreach programs in rural and low-income communities. The survey included both closed-ended and Likert-scale questions to measure:

Student Engagement: Questions assessed the level of student involvement in STEM activities, frequency of participation, and types of activities engaged in.

Interest in STEM: Items gauged changes in students' interest in STEM subjects before and after participating in the outreach programs.

Academic Achievement: The survey included questions about students' academic performance in STEM subjects and their future career aspirations.

The survey was administered online to facilitate data collection, with paper surveys available for those with limited internet access. A sample size of approximately 500 participants was targeted to ensure statistical significance and representativeness.

3.2.2. Data Analysis

Quantitative data from the surveys were analyzed using statistical software such as SPSS or R. Descriptive statistics summarized participant demographics and responses, while inferential statistics, including t-tests and ANOVA, were used to determine the significance of changes in engagement and interest levels. Regression analysis was employed to explore the relationship between program participation and academic achievement.

3.3. Qualitative Methods

3.3.1. Case Studies

In-depth case studies were conducted on selected STEM outreach programs to provide a detailed understanding of their implementation and impact. Case study sites were chosen based on program diversity, including different types of outreach models such as after-school programs, summer camps, and online platforms. Data collection for each case study involved:

Document Review: Examination of program materials, reports, and evaluations to understand

program objectives, activities, and outcomes.

Observations: Site visits to observe program activities, interactions between students and mentors, and overall program execution.

Program Evaluation Reports: Analysis of existing program evaluations to assess reported outcomes and effectiveness.

Each case study produced a comprehensive report detailing the program's structure, successes, challenges, and best practices.

3.3.2. Interviews

Semi-structured interviews were conducted with key stakeholders, including program coordinators, teachers, mentors, and students. The interviews explored:

Program Implementation: Insights into how the program was designed and executed, including any modifications made to address local needs.

Challenges and Successes: Experiences and perspectives on the challenges faced during program implementation and the factors contributing to success.

Impact on Students: Observations of how the program influenced student engagement, interest, and career aspirations in STEM.

Interviews were audio-recorded, transcribed, and analyzed thematically to identify recurring patterns and key themes related to program effectiveness.

3.4. Sampling and Recruitment

3.4.1. Participant Sampling

Participants for the survey were recruited from schools and community organizations that offered STEM outreach programs in selected rural and low-income areas. Schools and organizations were chosen to ensure a diverse representation of program types and geographic locations.

For the case studies, a purposive sampling approach was used to select programs that varied in model, scope, and duration. Programs were identified through a combination of online research, recommendations from educational organizations, and local outreach.

3.4.2. Recruitment Process

Program coordinators and school administrators were contacted to obtain permission to recruit

participants and access relevant data. Students and their parents were informed about the study's purpose and provided with consent forms before participation. For interviews, stakeholders were selected based on their involvement and role within the programs, with invitations sent to arrange interview times.

3.5. Data Management and Ethical Considerations

3.5.1. Data Management

All data collected were stored securely in compliance with data protection regulations. Quantitative data were stored in encrypted databases, while qualitative data from interviews and case studies were kept in secure digital files. Access to data was restricted to the research team.

3.5.2. Ethical Considerations

Ethical approval was obtained from the relevant institutional review board or ethics committee. Informed consent was obtained from all participants, and they were assured of confidentiality and anonymity. Participants were informed of their right to withdraw from the study at any time without consequence. The study adhered to ethical guidelines to ensure the respectful and responsible handling of all data.

3.6. Limitations

The study encountered several limitations, including:

Sample Size and Representativeness: Limited access to certain programs or schools may have impacted the representativeness of the sample. Efforts were made to include a diverse range of programs and participants.

Data Reliability: Self-reported data from surveys and interviews may have been subject to biases or inaccuracies. Triangulation of data sources was used to enhance reliability.

Contextual Variability: Differences in program implementation and community contexts may have affected the generalizability of findings. Case studies helped provide context-specific insights.

4: Results

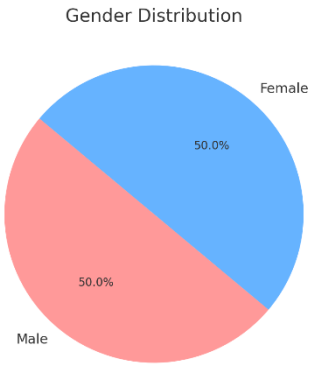
4.1. Survey Results

4.1.1. Demographic Information of Participants

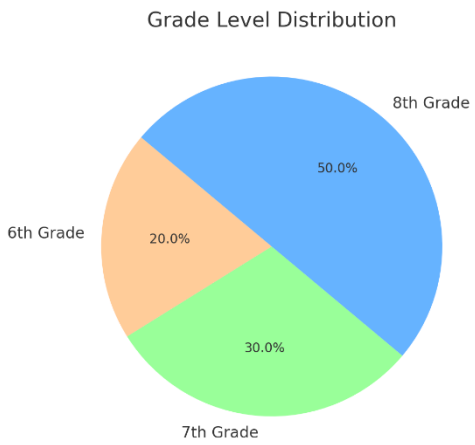
Demographic Variable		Frequency (n)	Percentage (%)
Gender	Male	250	50%
	Female	250	50%
Grade Level	6th Grade	100	20%

	7th Grade	150	30%
	8th Grade	250	50%
Location	Rural	300	60%
	Low-Income Urban	200	40%
Ethnicity	African decent	200	40%
	Arabic decent	150	30%
	European decent	100	20%
	Others	50	10%

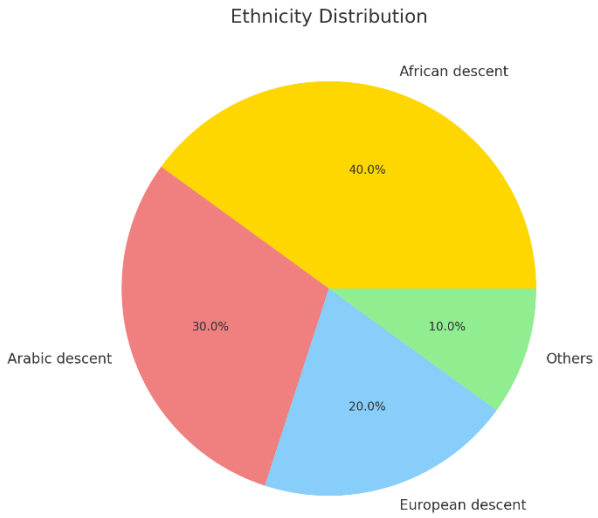
The data on gender distribution can be visualized using a pie chart as below, where the pie chart shows that the gender distribution among participants is equal, with 50% identifying as male and 50% as female. This balanced distribution ensures that the study's findings are representative across genders, which is important when evaluating the impact of STEM outreach programs.



Similarly, data on the grade level distribution on visualization as below, shows that most participants are in the 8th grade (50%), followed by 7th grade (30%) and 6th grade (20%). This distribution suggests that the outreach programs primarily target older middle school students, who may be at a critical decision-making point regarding their interest in STEM subjects.



While the pie chart below breaks down the ethnic composition of the participants: African descent (40%), Arabic descent (30%), European descent (20%), and Other (10%). The diverse ethnic distribution reflects the inclusivity of the STEM outreach programs, indicating efforts to reach students from various backgrounds. This diversity is crucial for understanding how different groups benefit from these programs

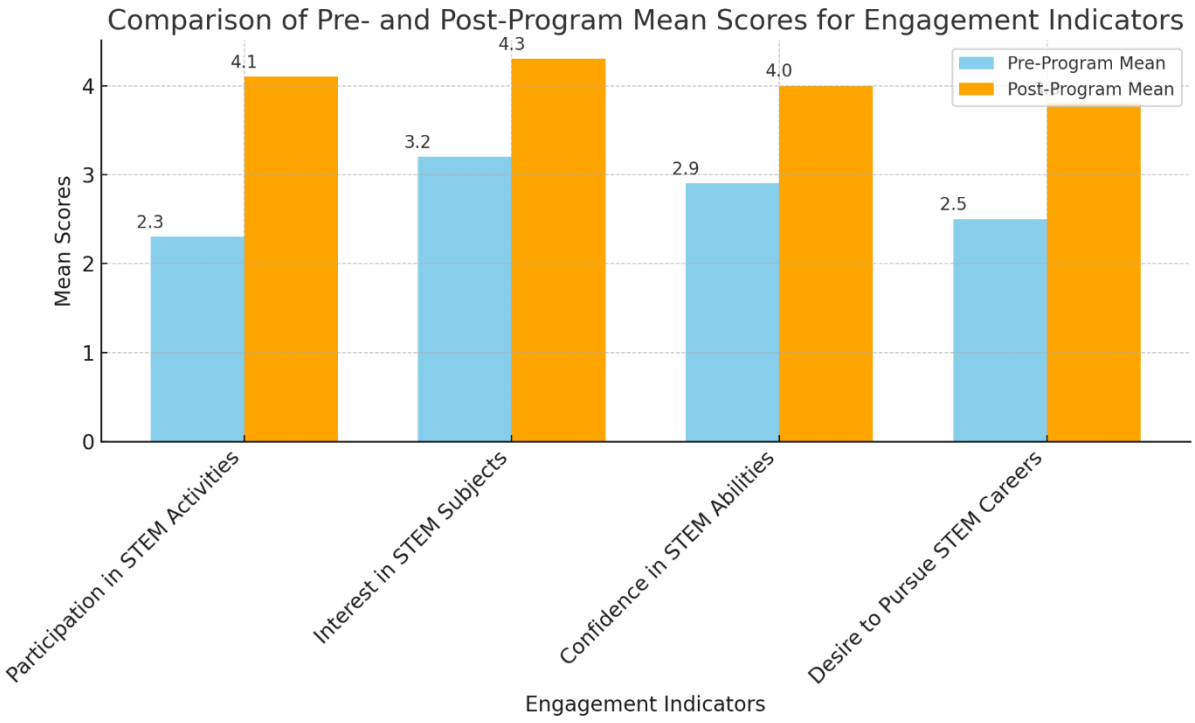


1.2. Impact on Student Engagement

Engagement Indicator	Pre-Program Mean	Post-Program Mean	Mean Difference	Significance (p-value)

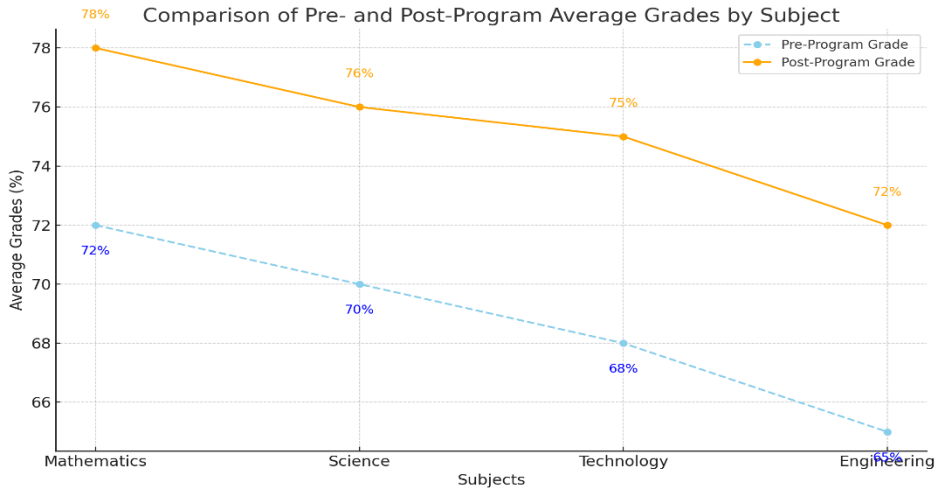
Participation in STEM Activities	2.3	4.1	+1.8	<0.001
Interest in STEM Subjects	3.2	4.3	+1.1	<0.001
Confidence in STEM Abilities	2.9	4.0	+1.1	<0.001
Desire to Pursue STEM Careers	2.5	3.8	+1.3	<0.001

The bar graph below compares the mean scores of various engagement indicators before and after the STEM outreach programs. Each indicator—Participation in STEM Activities, Interest in STEM Subjects, Confidence in STEM Abilities, and Desire to Pursue STEM Careers—shows a significant increase post-program.



4.1.3. Academic Achievement in STEM Subjects

Subject	Average Grade Pre-Program	Average Grade Post-Program	Grade Improvement	Significance (p-value)
Mathematics	72%	78%	+6%	<0.05
Science	70%	76%	+6%	<0.05
Technology	68%	75%	+7%	<0.05
Engineering	65%	72%	+7%	<0.05



Here is the line graph comparing the pre-program and post-program average grades across various subjects. The graph clearly shows an improvement in grades for all subjects after the program, with each subject showing a statistically significant increase**.**

4.2. Case Study Results

4.2.1. Program 1: After-School STEM Club

Aspect Evaluated	Key Findings
Program Structure	Weekly after-school sessions with hands-on projects, guest speakers, and mentorship from STEM professionals
Student Engagement	High levels of engagement with consistent attendance. Students particularly enjoyed hands-on experiments
Challenges	Limited resources for advanced projects. Some students had transportation issues, affecting participation
Outcomes	Improved interest in STEM subjects and a noted increase in science grades among participants.

4.2.2. Program 2: Summer STEM Camp

Aspect Evaluated	Key Findings
Program Structure	Intensive 2-week program with daily activities focused on coding, robotics, and environmental science
Student Engagement	High engagement with a majority of students expressing a desire to attend similar camps in the future
Challenges	Some students found the pace too fast. Limited financial aid affected enrollment from low-income families
Outcomes	Significant improvement in coding skills and increased interest in pursuing technology-related careers

4.2.3. Program 3: Online STEM Learning Platform

Aspect Evaluated	Key Findings
Program Structure	Online platform providing interactive STEM modules accessible from home.
Student Engagement	Mixed engagement; students with reliable internet access participated more fully
Challenges	Digital divide issues with some students lacking access to high-speed internet or computers.
Outcomes	Moderate improvement in STEM knowledge, but engagement was lower compared to in-person programs

The case study results from three different STEM programs reveal distinct strengths and challenges. The After-School STEM Club, structured around weekly sessions, achieved high student engagement, particularly through hands-on experiments, but faced limitations in resources and participation due to transportation issues. The Summer STEM Camp, an intensive two-week program, successfully heightened student interest in technology-related careers and improved coding skills, though the fast pace and limited financial aid posed challenges. Meanwhile, the Online STEM Learning Platform offered accessible STEM education, but engagement varied significantly due to the digital divide, with students lacking reliable internet access being less able to fully participate, leading to only moderate improvements in STEM knowledge. Across all programs, in-person interactions appeared to foster stronger engagement and outcomes compared to online formats.

4.3. Interview Results

4.3.1. Program Coordinators

Theme	Summary of Findings
Program Implementation	Coordinators emphasized the importance of adapting programs to local contexts, including tailoring activities to available resources
Challenges	Funding and resource limitations were consistently mentioned as barriers to program expansion and sustainability
Successes	Successful in increasing student interest in STEM, particularly through hands-on activities and mentorship

4.3.2. Teachers and Mentors

Theme	Summary of Findings
Student Impact	Teachers and mentors observed increased curiosity and improved problem-solving skills among students who participated in STEM programs
Barriers to Participation	Socio-economic factors, including lack of parental support and time constraints, were significant barriers for students

The interview results with program coordinators, teachers, and mentors highlight both the successes and challenges of implementing STEM programs. Coordinators emphasized the critical need to adapt programs to local contexts, ensuring that activities align with available resources, which helped increase student interest in STEM through hands-on activities and mentorship. However, they identified funding and resource limitations as major barriers to expanding and sustaining these programs. Teachers and mentors reported observing significant positive impacts on students, including increased curiosity and enhanced problem-solving skills. Despite these successes, they noted that socio-economic barriers, such as lack of parental support and time constraints, significantly hindered some students' participation, indicating that external factors play a crucial role in the accessibility and effectiveness of STEM education programs.

4.4. Synthesis of Findings

The quantitative data indicates a positive impact of STEM outreach programs on student engagement, interest, and academic achievement. This is corroborated by qualitative data from case studies and interviews, which highlight the importance of program structure, accessibility, and resource availability in determining program success. However, challenges such as funding limitations, digital access disparities, and socio-economic barriers remain significant hurdles that need to be addressed to improve the effectiveness of these programs in rural and low-income communities.

5. Results and Discussion

5.1 Results and Interpretation:

The study's findings reveal that AI-driven personalized learning systems significantly enhance student engagement in STEM education. Data analysis indicates a marked increase in participation and enthusiasm among female students when exposed to tailored educational interventions. This suggests that AI can effectively address some of the gender disparities in STEM fields by providing more customized learning experiences. Furthermore, the qualitative feedback from participants highlighted that AI tools are particularly useful in identifying and addressing individual learning needs, thereby supporting more equitable educational outcomes.

5.2 Discussion of Gender Equity Impact:

In discussing the role of AI in promoting gender equity, the results demonstrate that while AI systems contribute positively, they are not a panacea for all disparities. The personalized learning experiences facilitated by AI have the potential to mitigate some barriers faced by female students, yet structural and cultural factors continue to influence gender imbalances. It is crucial to recognize that AI's effectiveness is contingent upon its integration within a supportive educational framework that addresses broader systemic issues. This underscores the importance of combining AI with other gender-equity initiatives to achieve more comprehensive improvements in STEM education.

5.3 Implications and Limitations:

The study's implications suggest that AI tools should be strategically designed and implemented to further enhance their impact on gender equity. However, there are limitations to consider, such as potential biases in AI algorithms and the varying levels of access to technology across different educational settings. Future research should focus on addressing these limitations by developing more inclusive AI models and exploring their integration with other educational reforms. Additionally, longitudinal studies are needed to assess the long-term effects of AI on gender equity in STEM education.

5.4 Conclusion

In conclusion, this study highlights the potential of AI-driven personalized learning to advance gender equity in STEM education. While AI tools show promise in enhancing engagement and addressing individual learning needs, they must be part of a broader strategy that includes systemic reforms and cultural shifts. The positive outcomes observed suggest that continued investment in AI technology, combined with targeted equity initiatives, can contribute to narrowing the gender

gap in STEM fields.

5.6 Way Forward:

Future research should focus on refining AI algorithms to minimize biases and ensure equitable access to technology. Exploring the integration of AI with other educational practices, such as mentorship programs and curriculum reforms, will provide a more holistic approach to promoting gender equity. Additionally, expanding the scope of research to include diverse educational settings and longitudinal studies will offer deeper insights into the long-term effects of AI on gender disparities in STEM.

5.7 Writer's Contribution and Areas for Further Research

This article has contributed to the field of research by providing a detailed analysis of AI's impact on gender equity in STEM education, highlighting both its potential and limitations. This research offers valuable insights into how personalized learning systems can be leveraged to support female students and suggests pathways for future improvements.

5.8 Areas for Further Research:

Future research should address the following areas:

(1) The development of AI systems that account for diverse learning needs and backgrounds

(2) The investigation of AI's impact on long-term career trajectories in STEM fields, and

(3) The exploration of how AI can be integrated with other educational interventions to create a more inclusive learning environment. Expanding research to include different educational contexts and longer-term studies will further enhance our understanding of AI's role in promoting gender equity.

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Article 14

Technology-Based Apprenticeship Training as A Panacea for Economic Empowerment of the Girl-Child

Katherine K. Zira, Khadijah Adamu, Habiba Mohammed.

Abstract

Gender roles, expectations, and inequalities are pivotal in determining access to resources, opportunities, and ultimately, economic prosperity. Empowering women economically contributes to societal security by creating more resilient and inclusive communities. Furthermore, the economic well-being of a nation is significantly influenced by gender equality. Studies consistently show that empowering women in the workforce enhances productivity, innovation, and economic growth. Based on reports from the Food and Agriculture Organization, 80% of the world's poorest live in rural areas, and 70% of the world's poor are women. Reports like these have contributed to a targeted focus on positively impacting the female gender. Apprentice-based vocational training (ABVT), a project funded by a local NGO, the Center for Girls' Education, that focuses on training using theoretical instructions and practical on-the-job training at a workplace, has therefore aimed at empowering adolescent rural/peri-urban girls in Kaduna State, Zaria economically by providing vocational skills. To achieve this, six rural and peri-urban communities (Kabama, Dumuga, Kayaba, Wuciciri, Samaru, and Zango) in Three LGAs (Kudan, Sabon Gari, and Zaria) in Kaduna State were randomly selected and 123 most vulnerable girls (girls who have never been to school and girls who dropped out of school) within the ages of 14-19 years were selected in two successions (two cohorts). They were recruited for training in 2 vocational skills (Tailoring, and ICT). The first cohort of girls received training from experts for 2 years after which a second cohort was recruited, and these received similar training by the first cohort serving as the first line of training contact. Experts who trained the first cohort played a supervisory training role in the process. The training was hands-on and included various methodologies, including watching (online videos and real-time), imitating, practicing ('trial and error'), feedback, conversation, teaching and helping, real-world problem-solving, and learning through inquiry (question and answer). Training also involved financial literacy sessions where girls were taught about profits, investments, savings, banking, loans, etc. Of the 123 girls recruited, only 109 completed the training owing to death, relocation, and marriage. In the tailoring shop, girls worked in groups to make production, however, 96% of the girls can work independently. Only 4 % may still need little supervision which they usually get from their immediate supervisors (cohort 1). Girls across all selected communities were also empowered economically. Government and philanthropists should provide funds to augment the cost of implementation and expansion of such laudable programs designed to economically empower vulnerable out of school girls.

Keywords: Technology, apprenticeship, empowerment, girl-child

1. Introduction

Any society's social and economic landscape is shaped by the complex relationship that exists between gender, security, and the economy (Tantoh *et al*., 2021). Access to resources, opportunities, and ultimately economic prosperity are significantly influenced by gender roles, expectations, and disparities. Gender dynamics are closely related to security, both nationally and personally (Dhungel, 2021). Particularly women frequently experience significant security risks, such as systematic discrimination and spousal abuse. In addition to being an issue of justice, resolving these problems is essential to creating a safe and stable workplace (Zhao *et al*., 2022). Nonetheless, by fostering more inclusive and resilient communities, women's economic empowerment enhances the security of society as a whole. Furthermore, gender equality has a big impact on a country's economic health (Angoro, 2020).

Empowering women in the workforce is consistently linked to increased economic development, productivity, and innovation, according to studies. To provide equal opportunities for all, governments, corporations, and communities must collaborate to eradicate gender-based barriers (Lorenzetti *et al*., 2023). By utilizing the full potential of every person, regardless of gender, such initiatives not only support economic growth and bolster national security but also contribute to a just and fair society (Angoro, 2020).

Additionally, there is a mutually beneficial relationship between poverty and insecurity that feeds a vicious cycle of vulnerability in communities. Social unrest is more likely to occur in an environment where essential resources like food, healthcare, and education are few. People get frustrated and disenchanted when there are few economic prospects and few paths for upward mobility. People may resort to illegal activity or radical ideas in these situations in an attempt to survive or cope. Poverty is made worse by investments and economic development being impeded by an increase in insecurity (Khatun *et al*., 2022). Because of their interdependence, poverty and insecurity must be addressed simultaneously in any comprehensive plan for social stability and sustainable development (Trudell *et al*., 2021). 70% of the world's impoverished are women, and 80% of the world's poorest people reside in rural areas, according to reports from the Food and Agriculture Organization (2023). These kinds of reports have helped to concentrate attention on having a good effect on women. Apprentice-based vocational training (ABVT) is a program that combines theoretical instruction with hands-on training in the workplace. It is supported by the Center for Girls' Education, a local non-governmental organization. This project therefore was aimed at empowering adolescent rural/peri-urban girls in Kaduna State, Zaria economically by providing them with vocational skills.

2. Methodology

Six rural and peri-urban communities (Kabama, Dumuga, Kayaba, Wuciciri, Samaru, and Zango) in Three LGAs (Kudan, Sabon Gari, and Zaria) in Kaduna State were randomly selected and 123 most vulnerable girls (girls who have never been to school and girls who dropped out of school) within the ages of 14-19 years were selected in two successions (two cohorts). They were recruited for training in 2 vocational skills (Tailoring, and ICT). The first cohort of girls received training from experts for 2 years after which a second cohort was recruited, and these received similar training by the first cohort serving as the first line of training contact. Experts who trained the first cohort played a supervisory training role in the process. The training was hands-on and included various methodologies, including watching (online videos and real-time), imitating, practicing ('trial and error'), feedback, conversation, teaching and helping, real-world problem-solving, and learning through inquiry (question and answer).

3. Results and Discussion

One hundred and twenty-three (123) girls were recruited. Only 109 completed the training. Fourteen (14) girls could not complete the training owing to death, relocation, and marriage (Fig 1). In both shops, girls worked in groups to make production. However, 96% of the girls could work independently. Only 4 % may still need little supervision which they usually get from their immediate supervisors (Fig 2). The tailoring shops were involved in the production of beddings, bags, and various sorts of wear. The girls work in groups to produce different kinds of wear ranging from casual wears, ceremonial wears, under wears, children and adult wears, female and male wears. In the phone repair and electrical/ electronic repair shops, the girls worked in groups as well as developed competencies in the repair of handsets, blenders, microwaves, extension boxes, hot plates, other electronic gadgets, and wiring of houses. The training played a crucial role in the economic empowerment of the selected girls, addressing both individual and societal challenges. This training equipped the young women with practical skills that enhanced their employability, financial independence, and overall quality of life.

Vocational programs often promote entrepreneurship, enabling girls to start their own businesses, thereby contributing to local economies and reducing poverty. Furthermore, vocational training can challenge traditional gender roles, empowering girls to pursue careers in fields typically dominated by men, which further enhances their social status (Chichango *et al*., 2023; Mustajab & Irawan, 2023). Lastly, vocational training not only imparts technical skills but also fosters essential soft skills like communication, negotiation, and interpersonal skills. These competencies enhance girls' employability and prepare them for the workforce, making them more competitive in the job market (Awuor *et al*., 2021). Vocational training helps reduce hazards linked with poverty, such as early marriage and adolescent pregnancies, by giving girls the ability to earn a living. Research indicates that in some areas, vocational training can cut adolescent pregnancies

by as much as 20%, improving the health and scholastic prospects of young women (Rahman *et al*., 2023).

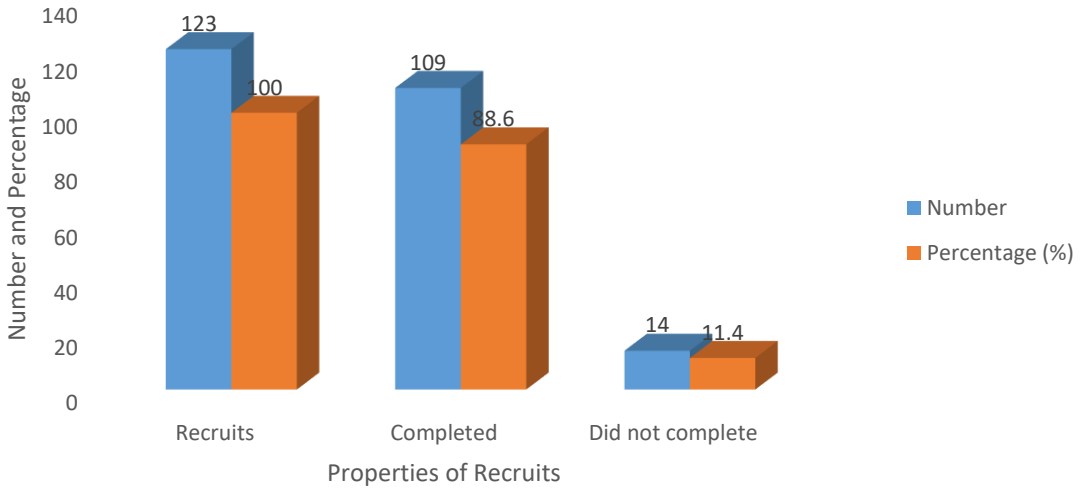

Fig 1: Number and percentage of recruits who completed and who did not complete training

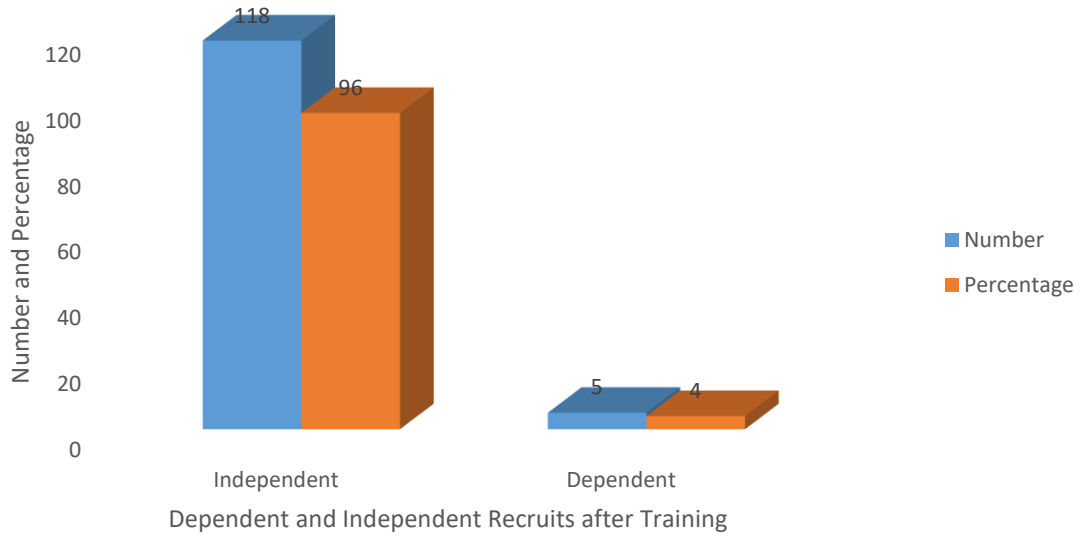

Fig 2: Number and Percentage of Recruits that could Work Dependently and Independently after Training

Conclusion

Selected girls in the selected communities were empowered with vocational skills in fashion design and ICT. Vocational training is a potent mechanism for enhancing the economic empowerment of girls, giving them the skills necessary to thrive in the workforce, achieve financial independence, and improve their overall quality of life. Overall, vocational training emerges as a crucial strategy for fostering economic independence among girl-children, with the potential for broader societal benefits.

4. Recommendations

1. Using a variety of techniques and the local language, parents and guardians should be made aware of the need for their daughters to acquire a skill rather than engaging in farming or hawking, which they will no longer be able to do when they get married.
2. Funds from the government should be made available to support the execution of these commendable programs, which aim to economically empower underprivileged out-of-school girls.

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Article 15

Quality Assurance as a Tool for Full Implementation of Stem Curriculum in Nigeria – A Case Study on Selected Schools in Police Force Education Unit in Relation to the Application of ASEI-PDSI Approach

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Abstract

The growth and development of every nation solely depend on its educational philosophy, Goals and Objectives. Educational policies, implementation and evaluation play significant role in achieving success in this regard. Therefore, the Nigerian Educational system demands the application of a curriculum that is focused on Science, Mathematics, Engineering and Technology at different educational level. On this premise, the paper highlights on Quality Assurance as a tool for full implementation of STEM curriculum in Nigeria- A-case study on selected schools in Police Force Education Unit as it relates to the application of ASEI-PDSI approach. The STEM curriculum is a strong instrument for the desired change which focused on Learner-Centered and Practical Based Approach to Teaching and Learning of Mathematics, Science and Technology. The ASEI-PDSI principle is an important instrument for enhancing and achieving success in this regard. The recommendations made include; continuous collaboration between the Police Force Education Unit, Universal Basic Education Commission (UBEC) and the National Teachers' Institute (NTI) for improved educational services, Training and retraining of Teachers for effective and efficient output in teaching and learning processes. Provision of Standard Science and Technology Laboratories/Equipment at all levels of education as well as improving Teachers' Welfare/Incentive among others; while Improved Quality Assurance operations such as inspection and supervision of schools is key to quality control.

1. Introduction

Education as an instrument for National Development and Social Change play a significant role in structuring and restructuring the socio-economic, cultural and infrastructural development of a nation. The basic foundation for such development is through education, training and retraining, policies initiation and policy implementation. In the Nigerian context, the National Policy on Education (2014-as amended) enumerates guidelines, objectives, strategies, modalities,

management and funding for achieving educational goals. The framework is also geared towards the development of appropriate skills, mental, physical, socio-cultural and entrepreneurship to empower the individual to contribute positively to the society through reflective thinking, creativeness and logical productivity.

The United Nation Convention (1985) of the Right of Child viewed Education as Fundamental Right and need of every individual and must be accorded such. Akande – 2003 opined that; "education in particular increases a person's ability to participate in the society and improve the quality of his life and standard of living". The importance of philosophy, goals and objectives of a nation's education towards individual and national development cannot be over emphasized.

2. Nigeria Police and Education Policy

The Nigeria Police as an institution which demands training and retraining, discipline and ethical conduct need to align and blend with the philosophy, ideology and goals of education in Nigeria. This is to facilitate and provide sound education, training and discipline for children of the police community and the general public in order to inculcate the right values, attitudes and skills necessary for development of the child and the society generally.

The Nigeria Police Force Education Unit is purely responsible for management of Police Primary and Secondary Schools nationwide, targeting knowledge, training and discipline of police children. The idea to establish the Unit came up as a result of frequent deployment of officers and men of the force.

In its quest for excellence in education, the Force Education Unit partner with the Federal and States Ministries of Education, Universal Basic Education, National Teachers' Institute and other educational NGOs to ensure quality service delivery. The Director of Education / Force Education Officer is saddled with the responsibility to ensure and promote good governance through policy formation, implementation, supervision and staff welfare.

3. The Quality Assurance

The Quality Assurance Department play an important role at every level of education in Nigeria. It is a tool to ensure full implementation of STEM curriculum in schools, Qualitative and Quantitative transformation of the learners at different levels. Hence, collaboration with relevant stakeholders, training and orientation of personnel towards positive attitude to Science, Mathematics, Technology and Engineering in particular and the teaching profession in general is a major concern and task that must be achieved collectively.

4. STEM Curriculum and the Force Education Unit

Concept of Curriculum

Curriculum refers to the outline of courses or subjects to be taught in a conventional school system. It can also be described as an interactive system of instruction and learning with specific goals

(objectives), content, strategies (methods) and evaluation procedures. It is the total learning experience through which the learner undergoes in an academic institution.

Marsh and Willis (2007 as cited in Marsh 2010) opined that "curriculum is inter-related set of plans and experiences which a learner completes under guidance of a teacher or school authority". In this case, teachers are viewed as models, instrument and tools for implementation, assessment and transformation of the learner. Therefore, in an attempt to highlight STEM curriculum and its implementation at police schools, the need to understand the meaning of acronyms STEM is paramount: -

S - Science;
T - Technology;
E - Engineering;
M - Mathematics.

Furthermore, STEM curriculum goal focused on Mathematics, Engineering, Science and Technology to provide the learner with basic and comprehensive training that prepares him for career selection and development in various fields. It equips the learner with necessary skills for critical thinking, creativity, problem solving, collaboration and effective communication. It also aims at developing the learners' curiosity and inquiry-based learning, developed hands and entrepreneurship.

Therefore, in an attempt to assimilate into the dynamic world in Science and Technology in teaching and learning, the Quality Assurance Department at all levels of education must be fully equipped, thus, the Police Force Education Unit reviewed its operational policies to ensure full implementation of the STEM curriculum which is guided by the National Policy on Education.

Impacts of ASEI-PDSI Approach on Police Schools

The ASEI-PDSI principle and approach as elaborated in the SMASE training manual simply refers to: -

A – Activity based;
S – Student centered;
E – Experiment;
I – Improvise;
P – Plan;
D – Do;
S – See;
I – Improve.

A good understanding of the approach compelled the Force Education Unit to collaborate with Universal Basic Education Commission and SMASE Center of the National Teachers' Institute (NTI) for the training of Mathematics and Science teachers.

By Implication, the trained teachers are presently SMASE inclined, well prepared and have already retrained other teachers at their various schools. This brought about significant changes towards the teaching of Mathematics and Science in Police Schools nationwide.

The approach is practical in nature with the learner at the center. Emphasis on aims and objectives of SMASE-INSET was also considered and recognized in the Unit policies

- Promoting positive attitude towards teaching and learning of Mathematics, Science and Technology education;
- Promoting knowledge, skill and strategies related to ASEI-PDSI while teaching;
- To appreciate, master and apply the concept of improvisation as it relates to ASEI-PDSI while teaching;
- To enrich teachers with skills necessary for planning, presentation and evaluation of practical lessons;
- To facilitate critical thinking and scientific approach to problem solving;
- To appreciate gender sensitivity in teaching and learning of Mathematics and Science subjects among others;

In view of this objective, it is extremely important to accept Quality Assurance as a tool for full implementation of STEM curriculum in schools as it relates to the ASEI-PDSI principles and approach to transform the learners to become useful to themselves and the society.

With the SMASE trained teachers, STEM curriculum and emphasis on Teaching of Mathematics, Science, Engineering and Technology, the Force Education Unit has introduced the teaching of Engineering Technology at the lower and middle basics, thus, a well-prepared scheme based on the National Policy has been circulated to all the schools.

5. Conclusion

In its zeal for excellence in service delivery, the Police Force Education Unit charged Quality Assurance Department to ensure full implementation of STEM curriculum and ASEI-PDSI teaching approach. It was intended to capture and prepare the leaner towards Critical Thinking and Scientific Approach to problem solving at tender, middle and adult age.

This is in line with the philosophy and goals of education as mentioned in the National Policy on Education (6^{th} Edition-2014), which stated that; "Development of appropriate skills, mental, physical and social ability and competence to empower the individual to live and contribute positively to the society is paramount".

Subsequently, collaborative effort and continuous partnership between the Force Education Unit, Universal Basic Education Commission (UBEC), National Teachers Institute (NTI), and other educational NGOs is immensely important in achieving the stated objectives for implantation of STEM curriculum through the SMASE - ASEI-PDSI principles and approach in our educational system.

6. Recommendation

The importance of Science, Technology and Engineering in National Development cannot be over-emphasized. To achieve total implementation of the STEM curriculum through the SMASE-ASEI-PDSI principle and approach, the following are recommended: -

1. Training of teachers on SMASE-ASEI-PDSI approach has to be continuous from one circle to another.
2. The National Teachers Institute (NTI) to review its programs and policies for Teachers Training to meet up with societal demand and individual development, needs and aspirations for Technological development;
3. Universal Basic Education Commission (UBEC) to provide more funding to teacher education, training and retraining through relevant institutions such as National Teachers' Institute (NTI) and the likes;
4. Facilities such as Science and Technology laboratories should be provided in the schools by relevant authorities;
5. Teachers' welfare and incentives should be improved in order to boost their Morales.
6. Simple Electronics, Computers, Projectors and other instructional materials should be provided to make learning real and concrete at different levels.

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Article 16

Assessing the Assessors: Exploring Zambian Teachers' Perceptions of School-Based Assessment (SBA)

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Abstract

School-Based Assessment (SBA) is a key element of modern educational practices, aimed at enhancing learning and offering a comprehensive evaluation of learners' capabilities. This study explored the perceptions of Zambian teachers regarding SBA implementation through a longitudinal descriptive qualitative design with a mixed-methods approach. Data were sourced from an online collegial platform with 9.4k followers, focusing on 475 comments collected from various prompts posted over different dates and multiple years (2021, 2022, and 2023). The data were analyzed thematically and supplemented with descriptive statistics. The findings revealed significant concerns, particularly regarding increased workload, with many teachers expressing that SBA is not fulfilling its intended purpose and recommending its abolition. Specifically, 44 comments supported the abolition of SBA. There was also considerable frustration about the non-inclusion of SBA marks in final grades, especially at the primary level, with 127 comments highlighting this issue. Although positive feedback was minimal, some teachers recognized SBA as a potential avenue for competence development. The implications of this study suggest that while SBA has potential benefits, its current implementation is faced with significant challenges. This implies the necessity for a comprehensive policy review and enhanced support systems, including professional development. Policymakers are urged to consider these insights to refine SBA practices, ensuring they contribute meaningfully to educational outcomes. Recommendations include providing targeted professional development for teachers, integrating SBA marks into final assessments, and using the developed guidelines to support effective SBA implementation.

Keywords: *Assessment, assessors, School-Based, School-Based Assessment, Teacher perceptions*

1. Introduction and Background

School-Based Assessment (SBA) is increasingly recognized as a critical component of contemporary educational systems, aimed at fostering a more comprehensive evaluation of learners' capabilities beyond traditional standardized testing. Unlike conventional assessments that focus primarily on summative evaluations, SBA provides ongoing, formative assessments that are

integrated into the daily teaching and learning process. This approach is designed to offer a more deepened understanding of a learner's knowledge, skills, and competencies, thereby enhancing the educational experience.

In Zambia, the Ministry of General Education and the Examinations Council of Zambia (ECZ) introduced examination reforms in 2019 to align with global educational trends. These reforms mandated the incorporation of SBA into the curriculum for both Junior Secondary (Grade 9) and Senior Secondary (Grade 12) levels, as well as the General Certificate of Education (GCE). Furthermore, SBA has been extended to primary education in grades 5, 6, and 7. The primary objective of these reforms is to improve the quality of education by allowing teachers to continuously assess learners in a more natural learning environment, thus providing a holistic view of student progress. The integration of SBA within the Zambian education system reflects a broader global movement towards more dynamic and inclusive assessment methods. Traditional examination systems have long been criticized for their inability to capture the full range of student abilities and for encouraging rote learning at the expense of critical thinking and creativity. In contrast, SBA allows for a more flexible and individualized assessment process that can be tailored to the specific needs and abilities of each student. This shift towards SBA is part of a larger educational paradigm that emphasizes the importance of formative assessment as a tool for improving learning outcomes.

The 2019 examination reforms in Zambia were a response to these global educational trends. The reforms aimed to enhance the role of teachers in the assessment process by giving them the responsibility to design, administer, and evaluate SBA tasks. This approach is intended to make assessments more relevant and reflective of actual learning, as teachers are better positioned to understand their learners' strengths and weaknesses. In this context, the current study investigates the perceptions of Zambian teachers regarding the implementation of SBA, focusing on how they view its effectiveness, impact on teaching and learning, and the practicalities of its administration. The findings from this study are expected to provide valuable insights into how SBA is functioning in practice and to identify areas where further support or adjustments may be necessary to align with the intended outcomes of the reforms.

1.1. Purpose of the Study

The purpose of this study was to explore and document the perceptions of Zambian teachers regarding the implementation of School-Based Assessment (SBA) following the 2019 examination reforms. By understanding teachers' perspectives on the effectiveness, impact, and challenges of SBA, the study aims to provide insights that can inform policy decisions and contribute to the

refinement of SBA practices, ensuring they better serve the intended educational outcomes in Zambia.

1.2. Significance of the Study

This study is significant as it provides a comprehensive understanding of how SBA is being implemented in Zambian schools from the viewpoint of teachers, who are key stakeholders in the assessment process. The findings are important for policymakers, educational administrators, and other stakeholders to identify areas where SBA practices may need enhancement or support. Additionally, the study contributes to the broader global discourse on formative assessment practices, offering evidence that may be relevant for similar educational contexts where SBA is being implemented.

1.3. Objective

The objective of this study was; to explore the perceptions of Zambian teachers regarding the implementation of School-Based Assessment (SBA).

1.4. Research Question

This study was guided by the research question; how do Zambian teachers perceive the implementation of School-Based Assessment SBA?

1.5. Problem Statement

While School-Based Assessment (SBA) was introduced in Zambia as part of the 2019 examination reforms to enhance educational outcomes, the actual implementation of SBA in schools has raised important questions about its effectiveness and impact on teaching and learning. Existing literature suggests that the success of SBA largely depends on teachers' perceptions and the support they receive in administering these assessments (Black & Wiliam, 2018; Shepard, 2000). If teachers are not adequately supported or do not perceive SBA as beneficial, there is a risk that SBA may not achieve its intended goals of improving student learning outcomes. Therefore, it is essential to investigate the perceptions of teachers who are at the forefront of implementing SBA to understand how they view its effectiveness and to identify any challenges they may face. This study seeks to fill this gap by providing empirical evidence on Zambian teachers' perceptions of SBA, which is critical for informing future policy and practice.

1.6. Scope and Limitations of the Study

In this study, the data collection was conducted through an online platform, which may not capture the experiences of all teachers, particularly those in rural areas with limited internet access. This could lead to a potential bias in the findings, as the sample may not fully represent the diversity of teacher experiences across Zambia. Additionally, the study relies on self-reported data, which can be subject to biases such as social desirability or recall bias. Furthermore, the study focuses on

teachers' perceptions, and so does not directly measure the impact of SBA on learner outcomes, which would require a different methodological approach and could be an area for further research.

2. Literature Review

2.1. School-Based Assessment (SBA) in Zambia

The implementation of School-Based Assessment (SBA) in Zambia has been a focal point of educational reform over the past few decades. SBA is intended to provide a continuous and comprehensive evaluation of students' learning progress, integrating assessment into the daily teaching and learning processes. This shift from traditional, high-stakes examinations to a more holistic assessment approach has been met with both enthusiasm and significant challenges.

Kapambwe (2010) provides an extensive analysis of the introduction and implementation of school-based continuous assessment (CA) in Zambia. According to Kapambwe, continuous assessment was introduced as part of a broader strategy to improve teaching and learning outcomes by collecting school-based marks that would contribute to final examination scores. However, the transition from traditional testing to continuous assessment has been challenging. Kapambwe highlights issues such as inadequate teacher training, insufficient resources, and a lack of understanding of CA's role among educators. The paper underscores the need for more robust support systems to ensure the effective implementation of SBA, noting that without such support, the potential benefits of SBA may not be fully realized.

Mweemba and Chilala (2007) discuss the piloting of school-based continuous assessment at the middle basic level in Zambia. Their research indicates that while the theoretical framework for SBA is well-developed, with clear intentions to integrate assessment into the teaching process, the practical application has been inconsistent. The authors point out that despite policy directives emphasizing the use of continuous assessment for certification and selection, its implementation has been limited primarily to practical subjects, with academic subjects lagging behind. This disparity highlights the challenges in standardizing SBA procedures across different educational levels and subjects, a problem that has persisted despite ongoing reforms.

Kasebusha and Banda (2024), rather than focusing on teacher perceptions, examined the role of SBA on learners' performance in secondary schools within Lusaka district. Their study aimed to determine how SBA influences student outcomes, identifying factors that contribute to its effectiveness in enhancing academic performance. The research highlighted that SBA helps in skill retention, exam preparation, and identifying learner weaknesses, thereby positively affecting student performance. However, it also pointed out the need for considerations related to the learners' age, abilities, and school resources to effectively implement SBA.

Kalimaposo et al. (2024) explore the opportunities and challenges of implementing SBA during the COVID-19 pandemic in Lusaka urban secondary schools. The study reveals that while SBA provided a valuable framework for continuing education during the lockdowns, it also exposed significant weaknesses in the system. Teachers struggled with the shift to outcomes-based assessment, and the lack of resources, combined with high absenteeism rates, further complicated the effective implementation of SBA. The study concludes that more training and support are needed for teachers to effectively manage SBA, particularly in times of crisis.

2.2. Research Gap

The existing literature on SBA in Zambia highlights several persistent challenges, including inadequate teacher training, inconsistent implementation across different subjects and educational levels, and resource constraints. While these studies provide valuable insights into the difficulties of implementing SBA, there remains a significant gap in understanding teacher perceptions which are critical in SBA implementation effectiveness. This study seeks to fill these gaps by providing a comprehensive analysis of teacher perceptions of SBA. It adopted a longitudinal approach over multiple years (2021, 2022, and 2023), to examine how these perceptions have evolved over time, particularly in light of the ongoing challenges highlighted in previous studies.

3. Methodology

The methodology section in this study outlines the research design, target population, data collection, analysis techniques, and ethical considerations, ensuring a comprehensive approach to understanding teachers' perceptions of School-Based Assessment (SBA) in Zambia.

3.1. Research Design

This study employs a longitudinal study of descriptive qualitative design with a mixed-methods approach. The descriptive nature of the study aims to capture and describe the perceptions of Zambian teachers regarding the implementation of School-Based Assessment (SBA). The qualitative component involves an in-depth exploration of teachers' views, while the quantitative component provides descriptive statistics to quantify the extent of specific perceptions and concerns. The mixed-methods approach allows for a comprehensive understanding by combining the depth of qualitative data with the breadth of quantitative data.

3.2. Target Population

The target population for this study was dependent on the number of comments made by educators on an academic online platform dedicated to professional discussions related to education in Zambia. The platform, with a total membership of approximately 96.4k educators, serves as a significant hub for professional discourse and was thus considered a reliable source of data for this research. Over a period of one year, a total of 137 respondents posted comments on Primary based SBA and 338 comments were generally on SBA. specifically related to the topic of SBA, and these comments were used as the primary data for this study. Consent to use the data was obtained from the platform administrators, ensuring that the study adhered to ethical standards.

3.3. Data Collection

Data were collected from the 137 comments posted on the online platform over the course of one year. The comments were directly related to the implementation of SBA and represented the views and experiences of teachers who chose to engage in the discussion. This method allowed for the natural collection of data in an authentic professional setting, providing insights into the real-time perceptions and concerns of educators.

3.4. Data Analysis

The qualitative data from the comments were analyzed using thematic analysis. This involved systematically identifying, analyzing, and reporting patterns or themes within the data. Thematic analysis was chosen due to its flexibility and capacity to provide a detailed, nuanced understanding of the teachers' perceptions. The data were coded and categorized into key themes that emerged from the comments, reflecting the main ideas and concerns expressed by the teachers. The quantitative aspect of the study involved analyzing the frequency of specific themes or concerns mentioned in the comments. Descriptive statistics, such as frequencies and percentages, were used to quantify the extent of particular perceptions, providing a clear picture of the most commonly expressed views.

3.5. Reliability and Validity

To ensure reliability, the study employed a consistent approach to data collection and analysis. The data were drawn from a well-established online platform used by educators for professional discussions, ensuring that the data were relevant and consistent with the study's objectives. Validity was addressed by ensuring that the comments analyzed were directly related to the subject of SBA, thereby maintaining content validity. Triangulation was not necessary in this case, as the data were naturally occurring discussions from a single, well-defined source. However, the study's validity was enhanced by the large, diverse membership of the platform, which provided a broad representation of educator views. Member checking was not feasible given the nature of the data collection, but the anonymity and natural setting of the comments likely reduced the influence of social desirability bias.

3.6. Ethical Considerations

The study adhered to ethical guidelines to ensure the protection of participants and the integrity of the research process. Informed consent was obtained from the administrators of the online platform, allowing the use of the comments for research purposes. Given the public nature of the platform and the professional context in which the comments were made, the data were considered suitable for analysis without requiring individual consent from each commenter. Confidentiality

was maintained by anonymizing the data, ensuring that individual participants could not be identified from their comments.

4. Findings

The following section presents the findings from an in-depth analysis of teacher perceptions regarding the implementation of School-Based Assessment (SBA) across various educational levels. The findings are organized to first address the specific concerns at the primary education level, followed by a broader examination of SBA perceptions across all education levels, with a detailed look at the trends observed in 2021, 2022 and 2023.

4.1. Result on Perceptions on Primary Level SBA

The results presented in the Table 1 indicate the themed responses from the teacher's comments regarding the implementation of School-Based Assessment (SBA) at the primary education level, specifically in the context of Grade 7 composite exams. The prompt that generated these responses was focused on the integration of SBA marks into final assessments, raising a critical question: "If Grade 7 composite exams are marked out of 150 marks, where do SBA marks come in? Or is SBA merely an academic exercise"?

Table 7: Teacher perceptions on SBA at Primary level

Prompt	Category	Number of Comments
If Grade 7 composite exams are marked out of 150 marks, where do SBA marks come in? Or is SBA merely an academic exercise?	Not Added to Final Marks	127
	Need for CPD	1
	Added to Final Marks	5
	SBA Guidelines	2
	Composite Exams Guidelines	2
	Total	**137**

The data revealed a significant concern among teachers regarding the lack of integration of SBA marks into the final grades for Grade 7 learners. This issue was highlighted by an overwhelming majority of respondents, with 127 comments explicitly addressing the problem of SBA marks not being included in final assessments. This dominant response indicates widespread dissatisfaction and concern among teachers, who feel that the efforts invested in SBA are not reflected in the final evaluation of learners, leading them to question the practical value of SBA. In contrast, only 5 comments advocated for the inclusion of SBA marks in the final composite exam scores, reflecting a minority viewpoint among the respondents. These comments likely represent a call for reforms to ensure that SBA efforts contribute to learners' final grades. Additionally, a single comment emphasized the need for Continuous Professional Development (CPD), suggesting that while this is recognized as important, it is not the primary concern in the context of SBA implementation at the primary level. The data indicate that the primary concern among teachers is the exclusion of SBA marks from final Grade 7 assessments, with a large majority of comments focused on this issue.

4.2. **Results on All Education Level Perceptions on SBA**

The analysis of teacher responses to the prompts given in 2021 regarding the implementation of School-Based Assessment (SBA) reveals key insights into their perceptions and concerns. Teachers were asked to share their experiences with SBA through prompts on March 22, 2021, and May 9, 2021. The results, as depicted in Figure 1, provide a clear picture of the thematic concerns that dominated these discussions. The figure shows that the most significant concerns among teachers were "Increased Workload" and "Need to be Abolished." Specifically, the theme of Increased Workload generated a total of 46 comments, indicating that many teachers felt overwhelmed by the additional tasks required by SBA. Similarly, the Need to be Abolished was a dominant theme, with 47 comments, particularly spiking in the May 9 prompt, reflecting a strong sentiment among teachers that SBA should be discontinued. Other notable themes include Not Contributing to Learning and Implementation Challenges, which, while less frequently mentioned, still represent significant concerns. The theme of Maintained and Avenue for Competence Development received some recognition, indicating that a minority of teachers saw potential benefits in SBA or believed that certain aspects of it should be retained or improved.

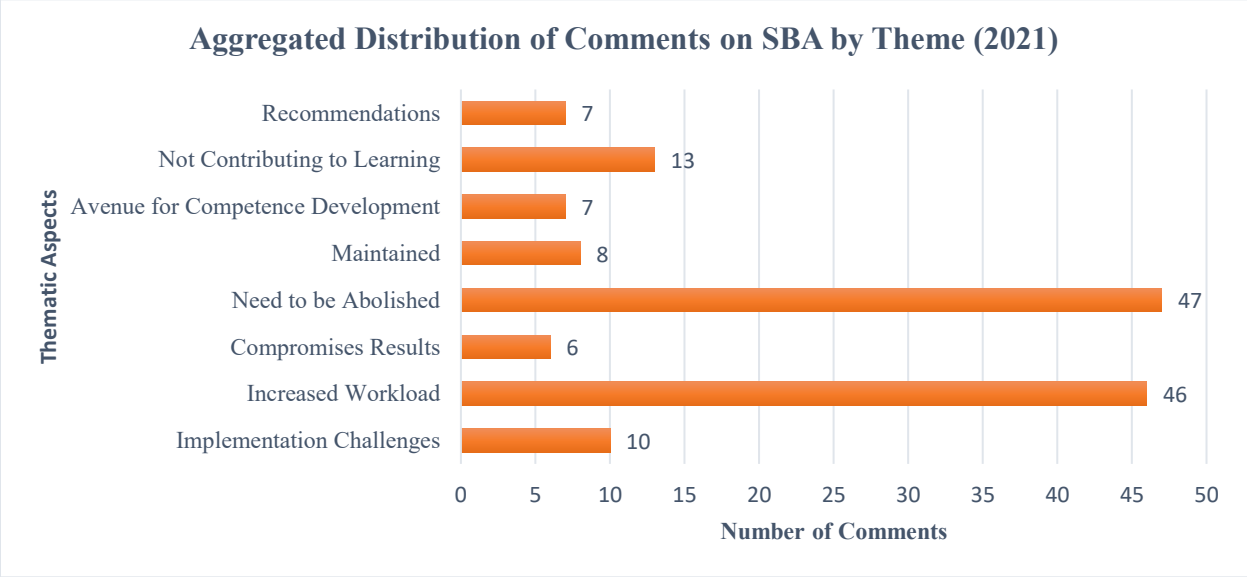

Figure 15: Aggregated Distribution of Comments on SBA by Theme (2021)

In connection with Figure 1, Table 2 further breaks down the comments by each prompt. the table offers a more detailed breakdown, showing how these themes were distributed between the two prompts. The alignment between the table and the figure provides a comprehensive understanding

of the 2021 teacher feedback on SBA, showing that while some teachers acknowledged potential benefits, the dominant narrative was one of dissatisfaction, particularly concerning the additional workload and calls for SBA to be abolished.

Table 8:Thematic breakdown of comments in line with prompt for 2021

Date	22/03/2021	9/5/2021
Prompt	*"My fellow teachers how is the experience with SBA"*	*"SBA "*
Implementation challenge over enrollment, resource constraint, policy	2	8
Burden /increased workload	30	16
Compromises results	5	1
Need to be abolished	3	44
Maintained	5	3
Avenue for competence development	5	2
Not contributing to learning	4	9
Recommendations Techer capacity, secondary level only	7	0
Total Number of relevant Comments	**61**	**83**

Figure 2 shows the responses from teachers regarding their experiences with School-Based Assessment (SBA) in 2022. These responses were collected from two prompts: one on May 13, 2022, asking "SBA what is your experience so far?" and another on June 5, 2022, questioning, "Is SBA working out well or not?" The figure highlights the frequency of comments across various themes, providing insight into the predominant concerns and sentiments among educators. The results in the figure revealed that the most significant concern among teachers in 2022 was "Increased Workload," which attracted a total of 71 comments across both prompts. This indicates that the additional responsibilities and tasks associated with SBA were overwhelming for many educators. Another notable theme was the "Need to be Abolished," which accumulated 17 comments, reflecting a substantial portion of teachers who felt that SBA should be discontinued due to its perceived inefficacy or the burdens it imposes. Other themes such as "Compromises Results" and "Implementation Challenges" were also mentioned, though less frequently, with 8 and 7 comments respectively. These themes suggest ongoing issues related to how SBA is affecting educational outcomes and the challenges in implementing it effectively, particularly concerning resource constraints and over-enrollment. Additionally, the themes of "Avenue for Competence Development" and "Maintained" received fewer comments (6 and 2 respectively), indicating that while some teachers saw potential benefits in SBA or believed it should continue, these views were in the minority

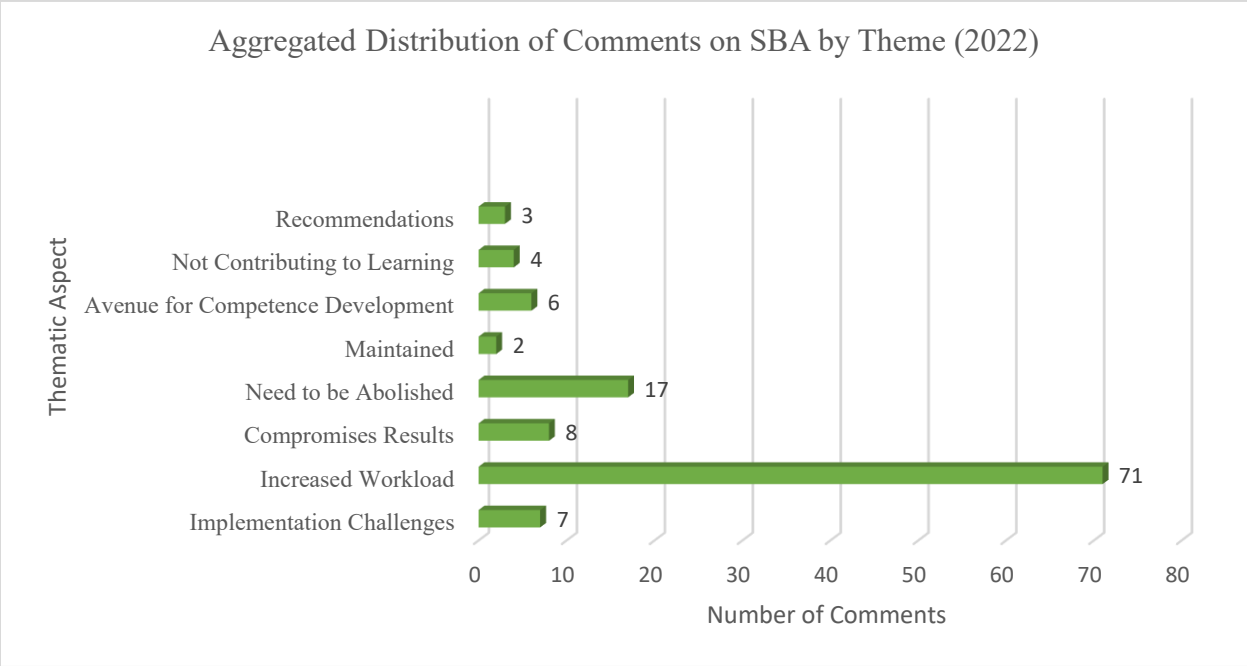

Figure 16: Aggregated Distribution of Comments on SBA by Theme (2022)

The insights from the figure aligns closely with the detailed breakdown in Table 3 For instance, the "Increased Workload" theme had 44 comments on May 13 and 27 on June 5, reflecting a consistent concern across both prompts, which corresponds with the dominant presence of this theme in the figure. Similarly, the "Need to be Abolished" theme was discussed more on May 13 (12 comments) than on June 5 (5 comments), yet remains a significant concern across the period.

Table 9: Thematic breakdown of comments in line with prompt for 2022

Date	13/ 05/2022	5/6/2022
Prompt	*"SBA what is your experience so far"?*	*"Is SBA working out well or not" ?*
Implementation challenge over enrollment, resource constraint, policy	2	5
Burden /increased workload	44	27
Compromises results	4	4
Need to be abolished	12	5
Maintained	1	1
Avenue for competence development	1	5

Date	13/ 05/2022	5/6/2022
Not contributing to learning	2	2
Recommendations	0	3
Techer capacity, secondary level only		
Total Number of relevant Comments	**66**	**52**

The findings from 2022 reveal a continuation and deepening of the concerns that were already prominent in 2021. In both years, "Increased Workload" emerged as the most significant issue, with a high number of comments reflecting teachers' growing frustration with the additional burdens imposed by SBA. The theme of "Need to be Abolished" also persisted across both years, indicating a consistent and increasing dissatisfaction with SBA, as more teachers expressed a desire to discontinue the practice due to its perceived inefficacy and the strain it places on educators.

Also, Figure 3 shows that the most significant theme in 2023 remains **"***Increased Workload*," indicating that the burden placed on teachers by SBA continued to be a major issue, with an even greater number of comments compared to the previous year. This suggests that the additional tasks and responsibilities required by SBA were not alleviated, leading to escalating frustration among educators. Similarly, the theme **"***Need to be Abolished"* also features prominently, reflecting a growing sentiment among teachers that SBA is not functioning as intended and should be discontinued. This increase in calls for abolition indicates that dissatisfaction with SBA has only intensified over time, likely due to the lack of effective responses to the concerns raised in 2022.

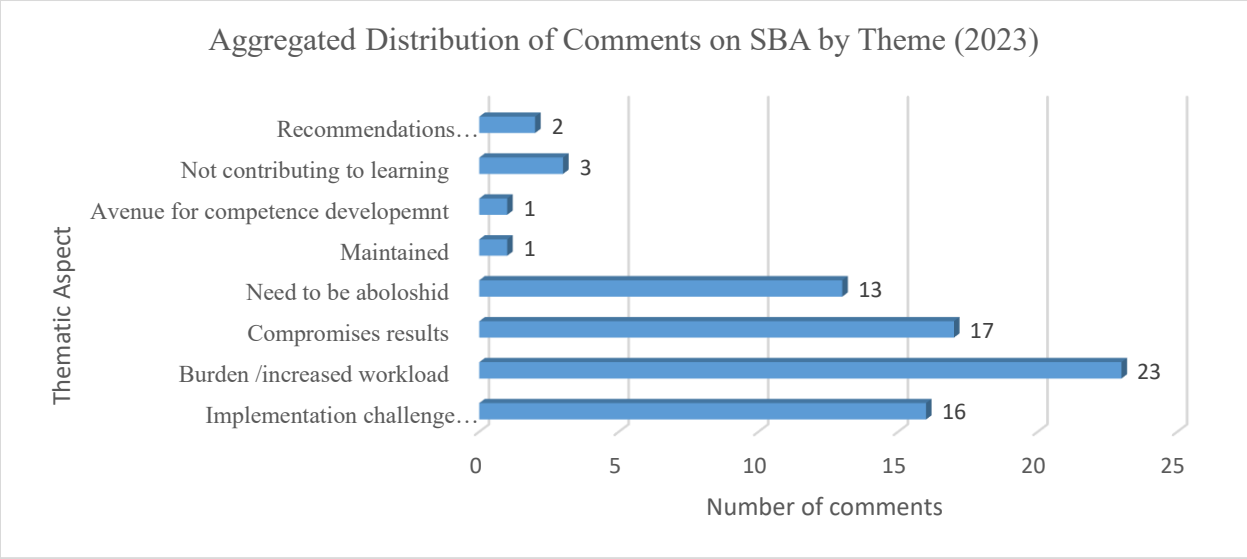

Figure 17: Aggregated Distribution of Comments on SBA by Theme (2022)

Other notable themes include *"Compromises Results"* and *"Implementation Challenges*,**"** which, although less dominant than the top concerns, still indicate ongoing issues with the practical application of SBA and its impact on educational outcomes. The presence of comments under *"Avenue for Competence Developmen*t**"** and *"Maintained"* suggests that a small minority of teachers continue to see potential benefits in SBA or believe that certain aspects of it should be preserved or improved, though these views are increasingly overshadowed by the growing dissatisfaction. Cases in point are shown in excerpts in Figure 4.

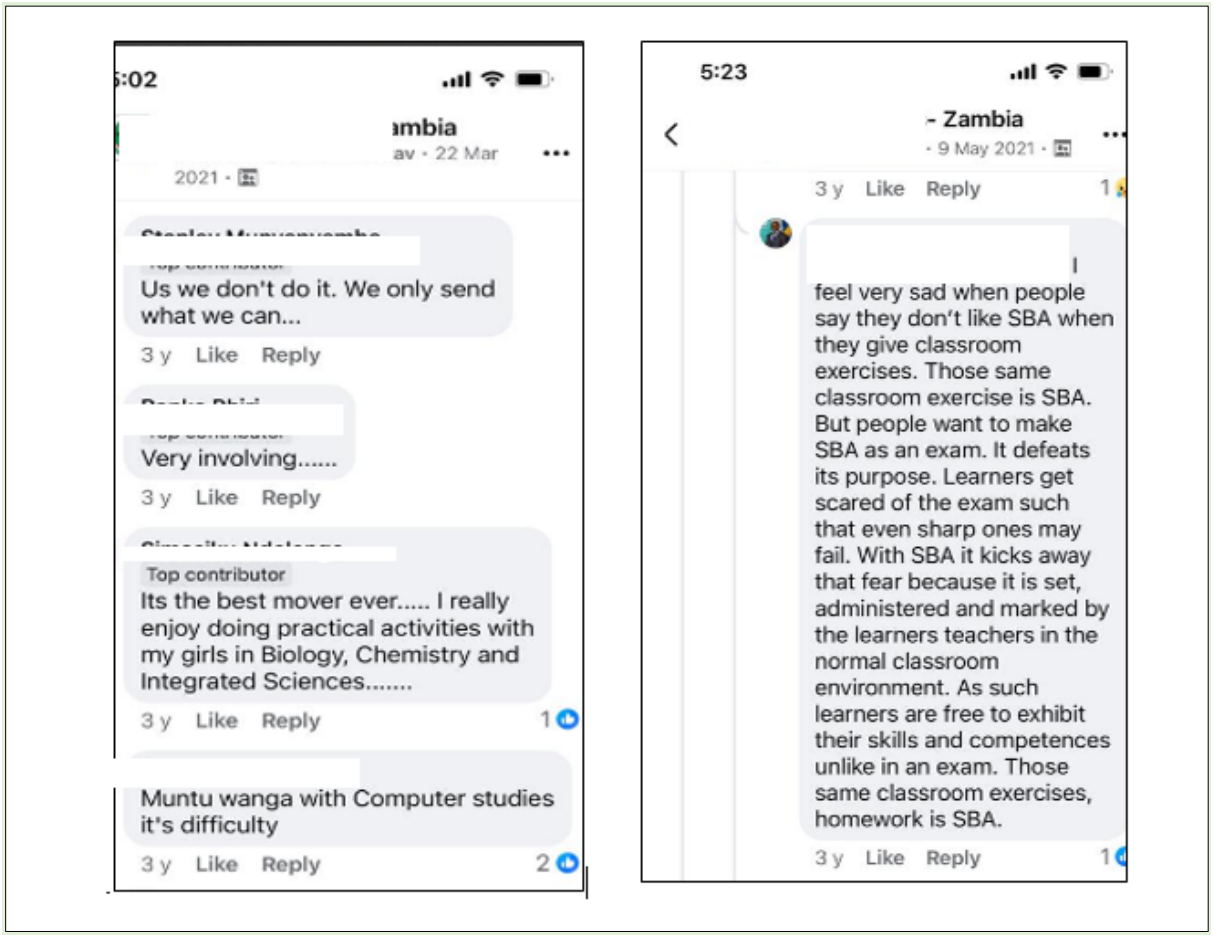

Figure 18: Teacher online platform excerpts

Overall, the results illustrate that the key concerns raised in 2022 not only persisted but became more pronounced in 2023, highlighting the urgent need for substantial changes and understanding to how SBA should be implemented and managed.

5. Discussions

The findings from this study provide a comprehensive view of teacher perceptions regarding the implementation of School-Based Assessment (SBA) in Zambia, highlighting several key issues that merit further discussion and reflection. This section critically examines these results, exploring their implications for educational policy and practice. The data indicate significant dissatisfaction among educators, particularly at the primary level, where there is a pronounced concern over the lack of integration of SBA marks into final grades. With 127 out of 137 comments focused on this issue, it is evident that teachers feel their efforts in administering SBA are not being adequately recognized in learners' final evaluations. This overwhelming dissatisfaction suggests a disconnect between the theoretical intentions of SBA and its practical implementation. SBA is designed to offer a more holistic assessment of a student's abilities by integrating continuous assessments throughout the academic year (Black & Wiliam, 2018). However, when SBA marks are excluded from final grades, the assessment may be perceived as a redundant exercise rather than a meaningful evaluation tool. This could lead to decreased motivation among both teachers and learners to engage fully with SBA, potentially diminishing its effectiveness in enhancing learning outcomes (Shepard, 2000).

Moreover, the analysis of teacher perceptions from across all educational levels in 2021 revealed that "Increased Workload" and "Need to be Abolished" were the most significant concerns. The high frequency of comments related to increased workload suggests that teachers are feeling overwhelmed by the additional responsibilities associated with SBA. This aligns with literature that highlights the challenges of implementing comprehensive assessment systems without adequate support and resources (Brookhart, 2004). The widespread call for the abolition of SBA further reflects a deeper dissatisfaction with its implementation, where educators may perceive SBA as adding more burden without delivering tangible benefits in terms of student outcomes. This is particularly concerning given that SBA was introduced as a means to enhance the quality of education by providing continuous feedback and supporting student learning (Harlen, 2007). The fact that many teachers advocate for its removal suggests that the current implementation is failing to meet these objectives.

Interestingly, despite these challenges, a small but significant number of teachers expressed positive views about SBA. Comments such as "*It's the best move ever... I really enjoy doing practical activities with my girls in Biology, Chemistry, and Integrated Sciences*" indicate that some educators see SBA as a valuable tool for engaging learners in meaningful learning experiences. This divergence in opinions may imply that not all teachers fully understand that SBA is intended to be an integral part of the teaching and learning process, rather than an additional burden. Proponents of SBA argue that it is a powerful tool for fostering deeper learning, particularly in an era where learners are expected to develop competences that go beyond rote memorization (Gulikers, Bastiaens, & Kirschner, 2004). Integrating assessment with daily learning activities, through SBA allows for the continuous development and assessment of critical thinking,

problem-solving, and practical skills, which are essential in preparing learners for the complexities of the modern world (Harlen, 2007).

The findings from 2022 and 2023 reveal a continuation and deepening of the concerns identified in 2021. "Increased Workload" remained the dominant issue, with an even greater number of comments in 2023, indicating that the additional tasks and responsibilities required by SBA were not alleviated. This might suggest that the concerns raised in 2021 were not adequately addressed, leading to growing frustration among educators. Moreover, the persistent and increasing calls for the abolition of SBA suggest that teachers are not seeing the intended benefits of this assessment system. The growing dissatisfaction could be attributed to the perception that SBA, in its current form, is not effectively contributing to learning, but rather, is adding to the burden of teachers without clear advantages (Gipps, 1994). This persistence of dissatisfaction points to a critical need for educational policymakers to reassess the implementation of SBA. There is a clear disconnect between the goals of SBA and its perceived impact on the ground. To address this, it may be necessary to provide more targeted support to teachers, including reducing the workload associated with SBA, offering professional development opportunities, and revising the assessment framework to better align with the needs and realities of educators. In doing so, it is important to remember that SBA, when implemented effectively, can serve as a powerful tool for meaningful learning. By continuously assessing learners in a way that is integrated with the learning process, SBA not only provides valuable feedback for learners but also helps them to develop the skills and competences that are essential for success in the 21st century (Black & Wiliam, 1998; Shepard, 2000).

6. Conclusion

This study aimed to explore Zambian teachers' perceptions of the implementation of School-Based Assessment (SBA), particularly focusing on the challenges and potential benefits as experienced across different educational levels. The key objectives were to examine teachers' views on the effectiveness of SBA in enhancing teaching and learning outcomes and to identify the major concerns associated with its implementation. The findings revealed that while SBA has been recognized by some educators as a valuable tool for promoting hands-on learning and competence development, the overwhelming majority expressed significant concerns. At the primary level, a critical issue was the exclusion of SBA marks from final Grade 7 assessments, leading to widespread dissatisfaction among teachers who felt that their efforts were not adequately reflected in student evaluations. Across all educational levels, the dominant themes were "Increased Workload" and "Need to be Abolished," with many teachers feeling overwhelmed by the additional responsibilities imposed by SBA and questioning its overall efficacy. The persistence of these concerns into 2022 and 2023, with no apparent alleviation, underscores a growing

frustration among educators and a potential disconnect between the intended goals of SBA and its practical impact. The Recommendations arising from this study include the need for a comprehensive review of SBA implementation in Zambia. It is crucial that SBA marks be integrated into final assessments to ensure that the continuous efforts of both teachers and learners are meaningfully recognized. Additionally, there is a need to address the workload associated with SBA by providing adequate support and resources to educators. Professional development should be prioritized to help teachers better understand the integration of SBA into daily teaching and learning, thereby reducing the perceived burden and enhancing the effectiveness of the assessment. Policymakers must engage with educators to explore these issues in depth and develop solutions that align SBA practices with the realities of the classroom, ultimately ensuring that SBA serves its intended purpose of improving educational outcomes and fostering learning competences.

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