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Editorial

PED Volume 42, Issue 2: Special Issue on Science Education Development in the Digital Age

Dear readers,

The publication of this Special Issue of *Papers in Education and Development (PED), Volume 42, Issue 2*, emerges as a key outcome of the *2nd China-Africa Forum on Science Education*, held on 12 July 2024 at the University of Dar es Salaam (UDSM), Tanzania. Co-hosted by the School of Education at UDSM and the College of Education at Zhanjiang Normal University, China, the forum brought together researchers, educators, and policymakers to explore the evolving landscape of science education in the digital era. Discussions highlighted how digital technologies are reshaping the teaching, learning, and assessment of science subjects—creating both opportunities and challenges for educators and learners. The forum centred on several critical themes, including:

- Opportunities and challenges of science education in the digital age.
- Science teacher education and professional development in digital contexts.
- Innovations in curriculum and pedagogy within technology-driven learning environments.
- Digital learning environments and assessment approaches.
- Inclusive science education through digital tools.

These discussions underscored the need to foster digital literacy among educators, reimagine pedagogical approaches, and ensure equitable access to digital resources, particularly in under-resourced settings.

Key Themes Emerging from This Special Issue

This Special Issue presents **eleven research articles** that examine diverse dimensions of science education development in the digital age. The contributions coalesce around several overarching themes:

Teachers' beliefs and ICT integration in science education

A significant theme in this issue revolves around teachers' beliefs, perceptions, and readiness to integrate ICT into science and mathematics instruction. Rimba and Tarmo examine how secondary school teachers' beliefs about ICT influence their adoption of digital technologies in science and mathematics classrooms. Similarly, Chuma and Raphael employed the Technology Acceptance Model (TAM) to examine how perceptions of usefulness and ease of use influence teachers' engagement with digital tools and ICT use in instruction. Collectively, these insightful studies underscore the need to address teachers' attitudes and digital literacy skills as fundamental prerequisites for ICT adoption in science education.

Pedagogical innovations and instructional strategies in science and mathematics

Several studies in this issue investigate the effectiveness of various teaching strategies in science and mathematics education. Buzza and Kitta provide empirical evidence for the superiority of experimentation methods in improving students' learning outcomes in geometry. Mhewa et al. focus on the jigsaw collaborative method and its impact on mathematics instruction, while Kahise explores the integration of neuroeducation principles into mathematics teaching, revealing gaps between theoretical knowledge and practical implementation. These studies highlight the importance of innovative pedagogies and active learning approaches that go beyond traditional rote-based instruction to foster meaningful learning experiences in science education.

Student participation and learning outcomes in science and mathematics

The factors influencing students' engagement in science and mathematics subjects also feature prominently. Kyaruzi's study identifies key predictors of students' participation in these subjects, including prior academic performance, teacher feedback, and parental education levels. Mbata, Timothy, and Maro investigate how guided inquiry-based experiments enhance students' acquisition of physics practical skills, advocating for experiential learning approaches in science education. These contributions reinforce the need for learner-centred pedagogical approaches to improve student engagement and achievement in STEM disciplines.

Digital technologies and inquiry-based learning in science education

The role of digital technologies and inquiry-based learning in facilitating science education is another critical theme explored in this issue. Manaseh's study examines the challenges and proposed initiatives for integrating digital technologies into primary school science education in rural Tanzania, highlighting the need for infrastructural support and policy interventions. Luvanga et al. investigate the opportunities for integrating inquiry-based learning in chemistry teaching, emphasising the potential of technology to enhance inquiry-driven learning. These studies underscore the importance of equipping schools with digital resources to support effective science teaching and learning.

Digital literacy and open educational resources (OER) teacher colleges and universities

Two studies focus on digital learning and curriculum relevance in teacher education and universities. Chalale et al. explore the perspectives of computer science student-teachers and tutors on the relevance of curriculum content for ICT-mediated teaching, calling for curriculum enhancements to align with digital education needs. Bhalalusesa examines the challenges and perceptions surrounding Open Educational Resources (OER) in Tanzanian higher education institutions, advocating for policy frameworks and capacity-building initiatives to enhance OER adoption. These studies highlight the evolving role of digital literacy and open-access resources in shaping the future of science education in teacher training and higher learning institutions.

Conclusion

The articles in this Special Issue collectively offer a thorough understanding of science education in the digital era, addressing both its transformative potential and inherent challenges. The research highlights the need for:

- ✓ Holistic teacher professional development that integrates technical training and attitudinal change towards digital tools.
- ✓ Pedagogical innovations that enhance student engagement, inquiry-based learning, and critical thinking.
- ✓ Strategic policy interventions to bridge digital divides and promote equitable access to technology-enhanced learning.
- ✓ Capacity-building initiatives to support OER adoption and strengthen digital literacy in higher education.

As science education continues to evolve, collaborative efforts among educators, researchers, and policymakers will be critical in ensuring equitable and effective integration of digital technologies.

Acknowledgements

On behalf of the Editorial Board, I extend my sincere gratitude to the authors for their valuable contributions and to the reviewers for their insightful feedback, which has enriched the quality of this Special Issue. I also acknowledge the dedication of the Guest Editors, Dr. Albert Tarmo and Dr. Florence Kyaruzi, who worked closely with the Associate Chief Editor, Dr. Joseph C. Pesambili, in overseeing the editorial process. Their commitment has been instrumental in bringing this volume to fruition. We hope that the research presented here will inspire further studies, inform policy decisions, and contribute to science education reform in Tanzania and beyond.

Chief Editor
Prof. Eustella P. Bhalalulesa
Papers in Education and Development (PED)

CONTENTS

Teachers' Beliefs and Their Effects on the Use of ICT in Teaching Science and Mathematics in Tanzania

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Abstract

This study investigated secondary school teachers' beliefs about ICT use and their espoused use of ICT in teaching science and mathematics. Specifically, the study examined the relationship between teachers' beliefs about ICT use and their espoused use of ICT in teaching science and mathematics. It further assessed the effect of teachers' beliefs about ICT use in teaching science and mathematics. The study employed a cross-sectional survey design, involving 172 randomly selected science and mathematics teachers from Kibaha District in Pwani Region, Tanzania. The findings revealed that teachers held predominantly negative beliefs about ICT use, which corresponds with their limited adoption of ICT in teaching. Furthermore, a strong relationship was observed between teachers' beliefs about ICT use and their espoused ICT adoption in science and mathematics teaching. The study concludes that teachers' beliefs about ICT use significantly influence their espoused adoption of ICT in science and mathematics teaching. It is recommended that initiatives to enhance ICT adoption should focus not only on training and resource provision but also on transforming teachers' beliefs about ICT use, which appear to limit their likelihood of integrating ICT into science and mathematics instruction.

Keywords: *teachers' beliefs, educational technology, science education, mathematics education*

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Introduction

Globally, education systems are under pressure to produce innovative, creative, and competitive workforces to meet the demands of the twenty-first-century market economy. Among the approaches to improving learning outcomes and workforce performance is the incorporation of Information and Communication Technology (ICT) in teaching and learning (MoEST, 2023). ICT refers to a broad range of technological tools and resources used to create, communicate, disseminate, store, and manage information (UNESCO Institute for Statistics, 2009). ICT enhances the international dimension of educational services and eliminates geographical barriers to teaching and learning (UNESCO, 2002). This is because it allows teachers and students to access resources and communicate in real-time without geographical barriers. It minimises time and distance barriers because teachers and students can network and share resources, knowledge, and experiences through ICT devices (Cholin, 2005). This resonates with the recently revised Tanzania Education and Training Policy, which advocates ICT as an approach that enables teachers to "reach multiple groups of students simultaneously" even in remote schools where resources needed to deliver quality science and mathematics education are in short supply (MoEST, 2023, p. 45). Therefore, ICT is a useful tool for overcoming a lack of teaching and learning resources and improving teaching and learning quality.

The integration of ICT transforms teaching and learning processes by using student-centred methods that allow teachers to organize lessons and learners to actively participate in and control their learning based on their learning needs and interests (Byukusenge, Nsanganwimana, & Tarmo, 2024). This is consistent with Mayer's (2009) argument that ICT supports teachers in planning classroom activities, assigning diverse tasks to students, and monitoring their learning behaviours. More importantly, ICT functions as an invaluable administrative tool, streamlining the management of classroom and school logistics. For instance, it is employed to manage teacher-related data, including attendance, annual leave, job performance, and remuneration. Additionally, ICT plays a crucial role in collecting, storing, and retrieving information about students' academic progress and school fee payments (Hadjilhoma-Garstka, 2011).

Although the role of ICT in improving instructional quality is widely acknowledged, ICT integration in teaching and learning processes has been slow in Tanzania (Kafyulilo et al., 2015; Mtebe & Gallagher, 2022; MoEST, 2023). This is partly because the integration of ICT in teaching and learning processes requires a departure from traditional pedagogies (Byukusenge et al., 2024). Researchers attribute the lack of sustained adoption of ICT to structural barriers such as access to ICT facilities and equipment, low levels of knowledge and skills and a lack of institutional support (Kafyulilo et al., 2015; Njiku et al., 2022). In addition, recent studies have focused on the affective aspects of technology adoption including teachers' attitudes and beliefs (Njiku et al., 2020).

Historically, the Government of Tanzania banned the use of computers and television for teaching and learning in 1974. Instead, the schools were provided with radios to enable students to listen to the lessons prepared by the then Ministry of Education and broadcasted by Radio Tanzania, the state radio station (Hare, 2007). The restriction was lifted in 1984, and since then, Tanzania has been catching up with the adoption of digital technologies, particularly in science education. Notably, the government is cognisant of the value and efficacy of the effective use of ICT for national development. This is well reflected in its aspiration for Tanzania to become a middle-income country by 2025, as articulated in the Tanzania Development Vision 2025: "*These technologies [ICT] are a major driving force for the realization of the vision. They should be harnessed persistently in all sectors of the economy*" (URT, 2000).

As a result, the government through the then Ministry of Education and Vocational Training (MoEVT) formulated the ICT Policy for Basic Education, covering "Pre-primary, Primary, Secondary and Teacher Education, as well as non-formal and adult education" (MoEVT, 2007 p. i). The overarching objective of this policy was to integrate ICT in education to enhance the accessibility, equity, quality, and relevance of basic education. To this end, ICT was introduced at the classroom level to enhance the acquisition of knowledge and skills through improved teaching, learning, and assessment. For example, in teacher education, ICT integration commenced with the installation of basic ICT facilities in the government teacher training colleges. This was a joint project between the Government of Tanzania and the Swedish Government through the Swedish International Development Cooperation Agency (SIDA) (Hare, 2007; Mwalongo, 2011). The introduction of ICT curricula and courses aimed at training principals, tutors, and both in-service and pre-service teachers in ICT skills and pedagogies followed (Hare, 2007; Tilya, 2008). The impact of initiatives to train pre-service teachers was expected to spread to schools once these pre-service teachers began teaching (Kafyulilo et al., 2016).

There were efforts to train in-service teachers to use ICT for teaching through continuous professional development. A notable training of science and mathematics teachers for example was organised by the MoEVT in collaboration with the Japan International Cooperation Agency. The training aimed to equip science and mathematics teachers with ICT literacy and build their capacity to integrate ICT into classroom teaching. More than 2000 teachers from 858 schools were trained under the programme, which improved the academic performance of students in science and mathematics (Mtebe, Mbwilo, & Kissaka, 2016). Another notable initiative was the collaboration between the Government of Tanzania and the Global e-School and Communities Initiative (GESCI) through the African Digital Schools Initiative (ADSI). This project provided technical and strategic support for secondary schools in Tanzania's Pwani Region to integrate ICT (Kafyulilo et al., 2016).

Similarly, the Government of Tanzania in collaboration with the SIDA and International Institute for Communication and Development introduced training on the use of ICT for teaching secondary school science and mathematics using the Technological Pedagogical Content Knowledge (TPACK) framework (MoEVT, 2009; Swarts & Wachira, 2010). Teachers were expected to acquire content and pedagogic knowledge about the use and integration of ICT in teaching processes. In this project, universities and colleges were supported in offering ICT courses to instructors, and pre-service and in-service teachers. The aim was to equip teachers with the TPACK needed to use ICT in teaching science and mathematics. For example, Dar es Salaam University College of Education (DUCE) offered an ICT course to science and mathematics teachers which aimed to equip teachers with ICT skills and pedagogies for teaching science and mathematics at secondary schools (Swarts & Wachira, 2010).

Lastly, there have been efforts to deliver science and mathematics subject content for Ordinary level secondary education through the Internet. One of the notable initiatives was the establishment of an e-School forum aimed at supporting the introduction and use of ICT in secondary education in Tanzania (Hare, 2007). For example, the MoEVT in collaboration with Halotel Tanzania developed 70 topics and 147 sub-topics with different multimedia elements in science and mathematics (Mtebe et al., 2016). The multimedia content was made available online for teachers and students to access. The MoEVT also established TV and radio broadcasting programs such as Star TV broadcast programs on different subjects for secondary schools to integrate ICT in schools.

However, careful analysis of the initiatives to support the integration of ICT in Tanzania would reveal that the efforts were largely concerted at structural barriers to and enablers of ICT integration such as the establishment of ICT infrastructure, the provision of knowledge and skills through teacher training, and design and delivery of web-based resources, among others. The focus on structural barriers is further reflected in the most recent Education and Training Policy of 2014, the revised edition of 2023 which stipulates that "*the Government … will establish conducive environments for the delivery of education and training using ICT at all levels*" (MoEST, 2023 p. 46). Structural barriers are often described as first-order factors that determine the adoption of ICT in teaching and learning (Abedi et al., 2023). There were no initiatives to transform teachers' strongly held beliefs about ICT use and its effect on teaching and learning processes. Teachers' beliefs about ICT are described as second-order factors that strongly influence the adoption of ICT (Abedi et al., 2023). Consequently, the integration of ICT in teaching and learning is occurring at a relatively slower pace than expected.

Problem and its context

The Government of Tanzania, in collaboration with development partners, has invested adequate resources to support the integration of ICT in science and mathematics education as a strategic intervention and part of its national development vision to improve workforce training (MoEVT, 2007). Teachers at different levels have been trained to integrate ICT into their teaching, curricula have been revised to accommodate ICT as a subject, and ICT devices and systems have been installed in different education educational institutions from primary schools to universities, to improve the quality of teaching and learning processes (Hare, 2007; Swarts & Wachira, 2010). Yet, evidence indicates that teachers rarely use ICT as a pedagogical tool for teaching and learning (Kazola & William, 2016; Msele, 2012; Mwalongo, 2011; Ndibalema, 2014). As indicated in the Education and Training Policy (MoEST, 2023), "Tanzania still faces challenges in the use of ICT in teaching and learning" (p. 45). While much research has examined the role of external barriers to ICT integration in teaching (Kazoka, 2016; Mtebe et al., 2016; Tanzania TELECOMS, 2016), less research has examined how factors intrinsic to teachers, such as teachers' beliefs and attitudes, constrain teachers from fully integrating ICT in teaching and learning. This study, therefore, examined teachers' beliefs about ICT use and their espoused use of ICT in teaching science and mathematics in secondary schools. Specifically, the study intended to:

i. Explore teachers' beliefs about the use of ICT in teaching science and mathematics;

ii. Examine teachers' espoused use of ICT in teaching science and mathematics;

iii. Establish the relationship between teachers' beliefs about the use of ICT and their espoused use of ICT in teaching science and mathematics;

iv. Assess the effect of teachers' beliefs about ICT use in teaching science and mathematics.

Theoretical Framework

The technology acceptance model (TAM), which addresses the role of users' beliefs in influencing their use of technology (Davis, 2003), guided the study. The model is based on the theory of reasoned action (TRA) which proposes that individuals' beliefs influence their intentions and ultimately determine their behaviours (Ajzen & Fishbien, 2005). It was based on this assumption that we considered the TAM useful for examining teachers' beliefs about ICT use and their espoused use of ICT in teaching science and mathematics in secondary schools.

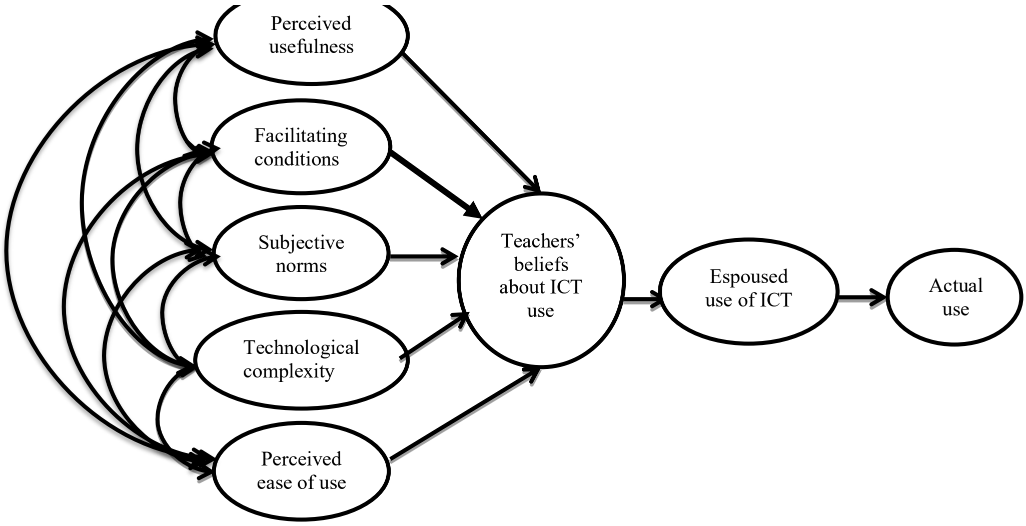

Figure 1: *Technology acceptance mode*

Teachers' beliefs about ICT use were theorised to have a direct effect on their espoused use of ICT in teaching science and mathematics (Liu, Koehler & Wang, 2018). TAM proposed that, when users interact with new technology, many variables influence their initial acceptance but perceived usefulness (PU) and perceived ease of use (PEU) are core variables that play a significant role in their continued acceptance and adoption (Davis, 2003). Further, Venkatesh et al. (2003) proposed that additional variables could be added as factors that influence users to accept and use technologies in TAM to the perceived usefulness and perceived ease of use. This study extends the TAM by adding variables such as facilitating conditions, subjective norms and technological complexity. These variables directly influence beliefs on ICT use to enhance the espoused use of ICT in teaching and learning science and mathematics that leads to actual usage.

The variables, subjective norms, facilitating conditions, technological complexity, perceived usefulness, and perceived ease of use, were used to build the study model. These variables provided the bridge between teachers' beliefs about ICT use and their espoused use of ICT in teaching science and mathematics. Espoused use of ICT was used as the main variable that determined the actual usage of ICT among teachers. Teachers' beliefs about ICT use acted as the independent variable. Espoused use of ICT acted as the dependent variable and was measured through teachers' beliefs about ICT use by using subjective norms, facilitating conditions, technological complexity, perceived usefulness, and perceived ease of use. Subjective norms can be determined by considering the perceived expectations of other individuals and their motivation to achieve.

Successful integration of ICT in teaching and learning depends largely on the teacher's support to use ICT. Facilitating conditions are factors that exist in the environment which influence a person's desire to use a certain technology (Teo & van Schaik, 2009; Venkatesh et al., 2003). For example, technical support is an important driver for teachers to use ICT for their instructional purposes. Technological complexity has a direct influence on beliefs about ICT uses. Hare (2007) observed that inadequate training towards ICT use in education hinders the integration of technology in teaching and learning. ICT use is perceived to be relatively easy to use when individuals are likely to develop positive beliefs towards its use and predict their espoused use of ICT in teaching and learning. Teo et al. (2009) found that perceived ease of use determines beliefs and intention to use technology. Perceived usefulness has an influence on beliefs towards ICT use and espoused use of ICT in teaching. For example, studies by Teo (2009) suggested that teachers use technology when they believe that it enhances performance in the teaching and learning process. Moreover, teachers' beliefs about ICT use were measured using subjective norms, facilitating conditions, technological complexity, perceived usefulness, and perceived ease of use.

Methodology

Research approach

The study employed a quantitative research approach because the research questions required the use of standard instruments to collect quantitative data, which was then subjected to rigorous statistical analysis. The study adopted a cross-sectional survey design.

Sampling and data collection

Structured questionnaires were administered to 172 out of the 181 science teachers employed to teach Physics, Chemistry, Biology, and Mathematics in the 15 secondary schools dispersed across Kibaha District in Tanzania's Pwani Region. The district has a well-established ICT in-service training centre, which trains science and mathematics teachers to integrate ICT into teaching and learning. Schools were clustered into private and public. Afterwards, stratified random sampling was used to select teachers considering gender and teaching subjects. Questionnaire items were adapted from those developed by Teo and Zhou (2014) and Teo (2012). The questionnaire comprised items measuring the seven constructs presented in the research model (see Figure 2). The constructs, with the respective number of items for each in brackets, were as follows: teachers' beliefs about ICT use (4 items), espoused use of ICT (3 items), perceived usefulness (4 items), perceived ease of use (4 items), subjective norms (3 items), facilitating conditions (4 items), and technological complexity (4 items). The questionnaires were administered to teachers, who responded to each item by selecting one of the five points along the Likert scale.

Data analysis

Data were analysed using Statistical Product and Service Solutions (SPSS) version 21 together with Analysis of Moments Structures (AMOS) 25.0. SPSS was used to run descriptive statistics while AMOS was used to build variable models. Structural equation modelling (SEM) was employed as the main technique for multivariate analysis in this study. SEM consists of two parts: the measurement model and the structural model. The measurement model was tested by using pooled confirmatory factor analysis, which combines all variables involved in the study, as shown in Figure 2.

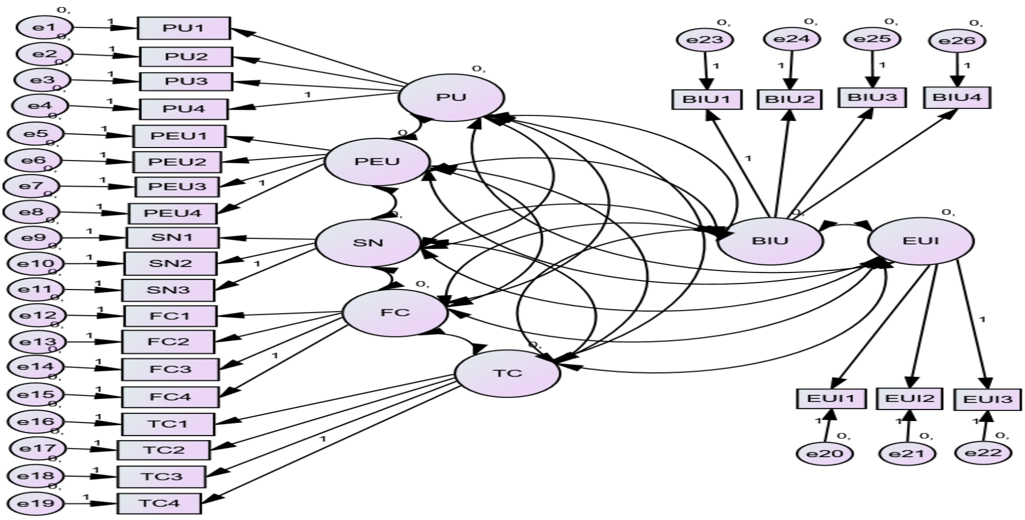

Figure 2: *Modelling the Measurement Model for Pooled Variables*

The model was assessed by using pooled confirmatory factor analysis (pooled CFA). Hair et al. (2010) suggest that any item having a factor loading less than 0.50 and squared multiple correlations less than 0.3 should be deleted from the measurement model. After executing pooled CFA, Figure 2 shows items FC2, FC3 and FC4 from the facilitating conditions (FC) variable and item TC4 from the technological complexity (TC) variable have low factor loading (below 0.5). These items caused the model to have poor fit hence deleted and run again the model.

Table 1

Pooled-CFA Reports for Every Variable in the Measurement Model

Construct	Code	Item	FL	t value	AVE	CR
PU	PUI	Using ICT will improve my teaching of science and mathematics.	.668		0.59	0.81
	PU3	Using ICT will increase my productivity.	.840	9.257		
	PU4	I find ICT a useful tool in my teaching of science and mathematics.	.782	8.779		
PEU	PEU1	I find it easy to get ICT to do what I want it to do.	.793		0.62	0.83
	PEU2	Interacting with ICT does not require a lot of mental effort.	.786	11.051		
	PEU4	Learning how to use ICT in teaching and learning is easy for me.	.780	10.956		
SN	SN1	People whose opinions I value will encourage me to use ICT in teaching.	.662		0.73	0.91
	SN2	People who are important to me will support me in using ICT in teaching science and mathematics.	.966	14.447		
	SN3	People who influence my behaviour will encourage me to use ICT in teaching science and mathematics.	.982	14.656		
	FC1	I have the necessary resources, such as a PC and internet access, for using ICT in teaching science and mathematics.	.613			
TC	TC1	Learning to use ICT in teaching takes up too much of my time.	.807		0.62	0.84
	TC2	Using ICT in teaching science and mathematics is so complicated that it is difficult to know what is going on.	.932	9.536		
	TC3	Using ICT in teaching science and mathematics requires too much time.	.578	7.681		
EUI	EUI1	I will always try to use ICT in my day-to-day teaching of science and mathematics.	.575		0.64	0.84
	EUI2	I plan to continue to use ICT when teaching science and mathematics.	.918	8.113		
	EUI3	I will use ICT frequently when teaching science and mathematics in the future.	.861	7.970		

BIU	BIU1	Using ICT in teaching science and mathematics makes work more interesting.	.669		0.54	0.82
	BIU2	Working with ICT in teaching science and mathematics is fun.	.693	7.787		
	BIU3	I like using ICT in teaching and learning.	.802	8.718		
	BIU4	I look forward to those aspects of my job that require me to use ICT in teaching.	.758	8.364		

Key: PU = Perceived usefulness, PEU = Perceived ease of use, SN = Subjective norms, FC = Facilitating conditions, TC = Technological complexity, EUI = Espoused use of ICT, BIU = Teachers' beliefs about ICT use.

Table 1 indicates that after removing the low-factor items and executing pooled CFA, results show certain fit indexes have not achieved the required level. The researchers have been required to modify a measurement model due to redundant items to achieve the required fit. After pooled confirmatory analysis, variables (PU, PEU, SN, TC, BIU and EUI) have achieved the acceptable composite reliability (CR) exceeding 0.60 and average variance extracted (AVE) exceeding 0.50. These results have a high level of validity and reliability in measuring a model. The estimated parameters were statistically significant at the $p < 0.05$ level, meaning that the value exceeded 1.96 for regression weights as indicated by the t-value. All variables have achieved the required level of estimation of greater than 0.5 for AVE. Further, the region of each estimated parameter to its standard error is statistically significant at a probability level less than 0.01 or 0.05 as indicated by the t-value. The path diagram in Figure 3 shows relationships between reflective variables in a model and the results that have been presented in Table 2.

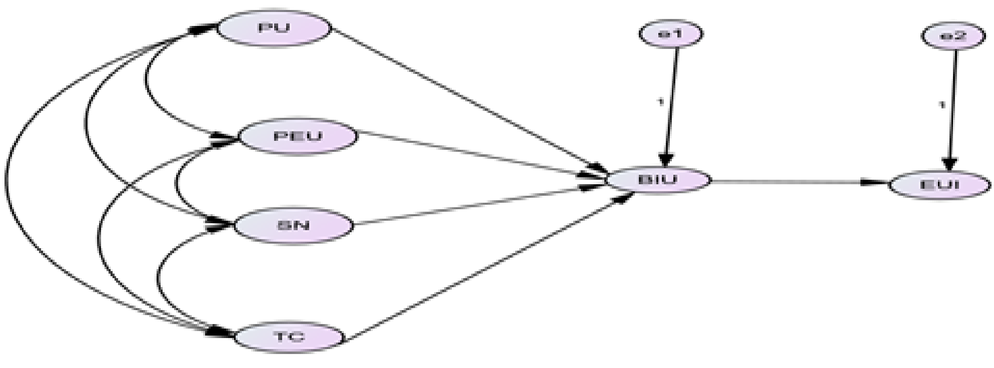

Figure 3: *Structural model*

Table 2

Discriminant Validity Assessment for Reflective Variables in the Model

Construct	PU	PEU	SN	TC	EUI	BIU
PU	**0.768**					
PEU	.208	**0.787**				
SN	.126	.196	**0.854**			
TC	-.038	-.085	-.009	**0.787**		
EUI	.036	.079	.037	-.061	**0.800**	
BIU	-.478	.853	-.041	-.024	.788	**0.735**

The findings in Table 2 indicate that the reflective variables (PU, PEU, SN, TC, EUI, and BIU) were strongly correlated with their indicators compared to the other variables in the model. The correlated variables with their indicators were shown as the square roots of AVE (in bold form). The square roots of AVE for the given reflective variables were greater than other variables, which indicated that the model was free from redundancy, so the model was deemed acceptable for further analysis. The results of the structural model indicate that there was a strong relationship among the variables influencing teachers' beliefs about ICT use and their espoused use of ICT in teaching science and mathematics in secondary schools. Teachers' beliefs about ICT use were explained by perceived usefulness, perceived ease of use, subjective norms, and technological complexity, which accounted for 17.8% of the variance found in teachers' beliefs about ICT use. Among the four variables measuring teachers' beliefs about ICT use in teaching science and mathematics, only perceived ease of use had a strong effect on teachers' beliefs about ICT use, while perceived usefulness, subjective norms, and technological complexity had only a weak effect. The strong effect may have been caused by the significant influence of perceived ease of use in teaching science and mathematics. The strong effect indicated a strong correlation between perceived ease of use and teachers' beliefs about ICT use in teaching science and mathematics. The weak effects may have been caused by the insignificant influence of perceived usefulness, subjective norms, and technological complexity. It indicates weak correlations between perceived usefulness, subjective norms and technological complexity and teachers' beliefs about ICT use in teaching science and mathematics.

The espoused use of ICT was determined by beliefs about ICT use, which explained 62.1% of the variance in the espoused use of ICT. The result shows a strong correlation between teachers' beliefs about ICT use and their espoused use of ICT in teaching science and mathematics. The results of the research model indicate that the majority of teachers had negative beliefs about ICT use in teaching science and mathematics. These negative beliefs might have been due to the weak correlations between perceived usefulness, subjective norms and technological complexity and teachers' beliefs about ICT use in teaching science and mathematics. Few teachers had positive beliefs about ICT use in teaching science and mathematics, and this might be due to the strong correlation between perceived ease of use and teachers' beliefs about ICT use in teaching science and mathematics. Teachers' espoused use of ICT was determined by their beliefs about ICT use through subjective norms, perceived usefulness, perceived ease of use, and technological complexity in teaching science and mathematics. Hence, teachers' espoused use of ICT influences actual use. Also, the region of each estimated parameter to its standard error was statistically significant at the probability level of less than 0.05; which means the values exceed 1.96 for regression weight as indicated by the t-value of the research model in terms of coefficient correlation and statistical significance.

Table 3

Results of the Research Model

Variable	Coefficients correlation	t-value	Result
BIU <--- PU	-.478	-.747	Not supported
BIU <--- PEU	.853	1.229	Supported
BIU <--- SN	-.041	.027	Not supported
BIU <--- TC	-.024	-.093	Not supported
EUI <--- BIU	.788	5.604	Supported
EUI <--- PU	-.377	-1.043	Not supported
EUI <--- PEU	.672	1.202	Supported
EUI <--- SN	-.032	-1.199	Not supported
EUI <--- TC	-.019	-.764	Not supported

The findings in Table 3 show that a probability level of less than 0.05 supports the results while a probability level of greater than 0.05 does not support the results as indicated by the t-value. Further, a strong correlation was indicated by the correlation coefficients of greater than 0.5 values, which support the results while the correlation coefficients of less than 0.5 values indicate low correlation, which does not support the results.

Results and Discussion

The results of this study are presented and discussed for each objective considering the analysis procedures described in Figure 2 and Figure 3 and Table 1, Table 2, and Table 3.

Teachers' beliefs about ICT use in teaching science and mathematics

Most of the science and mathematics teachers held negative beliefs about the use of ICT in teaching processes. Teachers' beliefs about ICT use depended on PU, PEU, SN, and TC. This means that teachers' beliefs about ICT use depended on teachers' support for using ICT, teachers' feelings about the benefits of using ICT as a pedagogical tool, and teachers' feelings on the usefulness and relative ease of use of ICT.

The path coefficient correlation from PEU to BIU was .853, PU had a coefficient correlation of – .478, TC had a coefficient correlation of – .024, and SN had a coefficient correlation of – .041 (see Table 3). BIU was significantly determined by PU, PEU, SN, and TC for 17.8% of the variance in BIU. The findings are supported by the path coefficient correlations between the variables. The results of the analysis show that among the four variables (PU, PEU, SN, and TC) that measured teachers' beliefs about ICT use in teaching science and mathematics, only perceived ease of use showed a strong effect of greater than 0.5 value on teachers' beliefs about ICT use. The strong effect of perceived ease of use on teachers' beliefs about ICT use reflects a strong correlation between perceived ease of use and teachers' beliefs about ICT use. The strong correlation between perceived ease of use and teachers' beliefs about ICT use indicates positive beliefs about ICT use in teaching science and mathematics. This means that teachers' perceived ICT as relatively easy to use strongly influenced their beliefs about ICT use in teaching science and mathematics. Teachers who had positive beliefs about ICT use were more likely to use ICT in their teaching processes compared to those with negative beliefs about ICT use.

Subjective norms (SN), perceived usefulness (PU), and technological complexity (TC) had a weak effect of less than 0.1 in measuring teachers' beliefs about ICT use in teaching science and mathematics. The weak effect of less than 0.1 indicates a low correlation between perceived usefulness, subjective norms, technological complexity, and teachers' beliefs about ICT use hence reflecting negative beliefs about ICT use in teaching science and mathematics. If teachers lack technical support, perceive ICT to be useless, and receive no encouragement to use ICT in their teaching, their beliefs about ICT use in teaching science and mathematics will be more negative.

BIU explained less than half (17.8%) of the variance in teachers' beliefs about ICT use among secondary school teachers. Only perceived ease of use influenced teachers' beliefs about ICT use in teaching science and mathematics. The influence of perceived ease of use on teachers' beliefs about ICT use indicates a strong correlation between perceived ease of use and teachers' beliefs about ICT use, thus indicating positive beliefs about ICT use among teachers. PU, SN, and TC did not influence teachers' beliefs about ICT use due to low correlation thus, reflecting negative beliefs about ICT use among teachers. This is despite the fact that teachers were trained through in-service training programs on how to integrate ICT into teaching. These findings are consistent with previous studies which have established that PEU is a core variable for determining teachers' beliefs about ICT use and their espoused use of ICT in teaching science and mathematics (Davis, 2003). Similarly, Compeau and Higgins (1995) found that teachers with positive beliefs about ICT use were able to use ICT more effectively and more often than those with negative beliefs. This is because they tend to hesitate to use ICT when they encounter obstacles.

Teachers' espoused use of ICT in teaching science and mathematics

The results showed that teachers in Kibaha District espoused limited actual use of ICT in teaching science and mathematics. Among the four variables measuring teachers' espoused use of ICT, only perceived ease of use showed a total effect of greater than 0.5 on the espoused use of ICT in teaching science and mathematics. The total effect of perceived ease of use on espoused use of ICT indicates a strong correlation between perceived ease of use and espoused use of ICT. This strong correlation creates actual use by showing positive beliefs about ICT use in teaching science and mathematics. This implies that when teachers perceive ICT to be relatively easy to use, it might cause them to develop positive beliefs about ICT use and hence could reinforce their espoused use of ICT that influences actual use. Further, SN, PU, and TC showed a total effect of less than 0.1 in measuring teachers' espoused use of ICT in teaching science and mathematics. This small total effect of perceived usefulness, subjective norms, and technological complexity indicates a low correlation between PU, SN, TC, and espoused use of ICT, thus creating limited usage of ICT. A low correlation indicates negative beliefs about ICT use in teaching science and mathematics. Convincing teachers to use ICT, supporting them in learning how to use it, and fostering the perception that ICT is both useful and easy to integrate into their teaching naturally cultivate positive beliefs about its use.

Further, the finding explained the variance greater than half (62.1%) in the espoused use of ICT among teachers teaching science and mathematics in the Kibaha District. Only PEU had a significant influence on teachers' espoused use of ICT in teaching science and mathematics (see Table 4). Thus, indicates a strong correlation between PEU and espoused use of ICT, which reflects positive beliefs about ICT use among teachers. Further, PU, SN, and TC had a non-significant influence on teachers' espoused use of ICT thus, indicating a low correlation between variables hence reflecting negative beliefs about ICT actual use among teachers (see Table

4). These findings concur with previous studies, which suggest that PEU is a significant determinant of intention to use ICT among teachers (Teo et al., 2009).

Table 4

Mediation Analysis

Effect	Path			Indirect effect	Direct effect	Total effect	VAF	Result
Direct without mediator	BIU	<---	PU	Not applicable	-.478	-.478		Not significant
	BIU	<---	PEU	Not applicable	.853	.853		Significant
	BIU	<---	SN	Not applicable	-.041	-.041		Not significant
	BIU	<---	TC	Not applicable	-.024	-.024		Not significant
	EUI	<---	BIU	Not applicable	.788	.788		Significant
Direct without mediator	EUI	<---	PU	Not applicable	-.399	-.776		Not significant
	EUI	<---	PEU	Not applicable	.546	1.218		Significant
	EUI	<---	SN	Not applicable	-.156	-.188		Not significant
	EUI	<---	TC	Not applicable	-.058	-.077		Not significant
Indirect with mediator	EUI	<---	PU	-.377	Not applicable	-.776		Not significant
	EUI	<---	PEU	.672	Not applicable	1.218	55.2%	Significant
	EUI	<---	SN	-.032	Not applicable	-.188		Not significant
	EUI	<---	TC	-.019	Not applicable	-.077		Not significant

These findings indicate that only PEU had a positive and significant influence on the espoused use of ICT through teachers' beliefs about ICT use, while PU, SN, and TC did not significantly influence the espoused use of ICT. This shows that teachers' beliefs about ICT use are representative of the relationship between PEU and EUI in teaching science and mathematics. Teachers' beliefs about ICT use have a variance accounted for (VAF) value of 55.2%.

Relationship between teachers' beliefs about ICT use and their espoused use of ICT

We found a strong relationship between teachers' beliefs about ICT use (BIU) and their espoused use of ICT(EUI) in teaching science and mathematics with a coefficient correlation of .788 which is significant at $p < 0.05$ level. EUI explained by BIU accounted for 62.1% of the variance found in EUI. Thus, findings indicate a strong correlation between BIU and espoused use of ICT by showing a strong effect of greater than 0.5. The results reflect positive beliefs about ICT use and hence reinforce teachers' espoused use of ICT which influences actual use in teaching science and mathematics. Positive beliefs about ICT use and their espoused use in teaching processes among teachers may be the result of encouraging teachers to use ICT in their teaching subjects, supporting them to use ICT, and teachers perceiving ICT as easy to use.

Furthermore, this finding explained more than half (62.1%) of the variance in the espoused use of ICT among secondary school teachers in the Kibaha District. The influence of teachers' beliefs about ICT (BUI) use predicts and has a significant influence on the espoused use of ICT (EUI) in teaching science and mathematics. Thus, indicates a strong correlation between BUI and EUI hence supporting positive beliefs about ICT's actual use among teachers. This result confirms the relationships between teachers' beliefs about ICT use and their intention to use ICT as explained by the Theory of Reasoned Action (Ajzen & Fishbein, 2005).

The effects of teachers' beliefs about ICT use in teaching science and mathematics

We found that teachers' beliefs about the use of ICT affected their use of ICT in teaching science and mathematics in secondary schools. The total effects of BIU caused by PU, PEU, SN, and TC ranged from – .478 to .853. PEU had a total effect of .853, PU had a total effect of – .776, SN had a total effect of – .188, and TC had a total effect of – .077. These results indicate that subjective norms (SN), perceived usefulness (PU), and technological complexity (TC) had a total effect of less than 0.1 on BIU, reflecting negative beliefs about ICT use in teaching science and mathematics. Only PEU had a total effect of greater than 0.5 on BIU, indicating positive beliefs about ICT use. These results show that when teachers perceive ICT as easy to use, they are more likely to use ICT in teaching science and mathematics. It is possible that the teachers in this study were affected by practical aspects of ICT use and made personal decisions on whether to use ICT as a teaching tool due to their negative beliefs about ICT use in teaching processes. Some studies have revealed that teachers' beliefs differ with their gender, study year, and subject domain (Beck et al., 2000). For example, of the 172 teachers who responded to this study, 102 teachers had received ICT training during pre-service teacher education, 139 teachers had received ICT training through in-service programs, 37 teachers had received both in-service and pre-service ICT training, and 166 teachers owned ICT tools and were aware of the use of ICT as a teaching tool. Further, the literature has shown that teachers use ICT to prepare notes and examinations (Mwalongo, 2011). In addition, 109 of the teachers in this study had been teaching for over 7 years. Richardson (2003) postulated that the number of years teachers have taught affects teachers' beliefs and practices.

Teachers' beliefs about ICT use affect their espoused ICT use in teaching science and mathematics. Among the four variables, measuring teachers' espoused use of ICT in teaching science and mathematics, subjective norms, perceived usefulness, and technological complexity had a total effect of less than 0.1 on the espoused use of ICT through teachers' beliefs about ICT use. This means that encouraging teachers, helping them learn how to use ICT, and supporting them to perceive ICT as useful in teaching and learning science and mathematics will help them to use ICT more effectively in their teaching. Only PEU had a total effect of greater than 0.5 on espoused use of ICT through teachers' beliefs about ICT use in teaching science and mathematics. These results echo those by Mwakapemba et al. (2024) who found that teachers had positive attitudes towards the use of government-supplied tablets for teaching. This implies that teachers perceiving ICT as easy to use enhances their positive beliefs about ICT use, which positively affects their espoused use of ICT in teaching science and mathematics. Teachers use ICT as a tool to enhance, enrich, and deepen the teaching processes. For example, teachers can use ICT to explain difficult concepts in Physics, Chemistry, Biology, and Mathematics that cannot be easily explained using text alone. In addition, teachers can use ICT to design teaching and learning environments to make it easier to access and view information by using multiple information resources. Generally, the results demonstrate the vital role that teachers' beliefs play when deciding to use ICT as a pedagogical tool (Deng et al., 2014).

Conclusions and Recommendations

This study found that most of the science and mathematics teachers hold negative beliefs about the use of ICT in teaching and learning. These beliefs significantly limit their espoused adoption of ICT in instructional practices. Moreover, a strong relationship exists between teachers' beliefs about ICT and their actual use of technology in science and mathematics teaching. Notably, deeply held negative beliefs exert a stronger influence on teachers' use of ICT in science and mathematics teaching than external factors alone. These results suggest that efforts to enhance the sustained adoption of ICT in teaching science and mathematics should extend beyond addressing contextual barriers, such as the supply of ICT equipment, teacher training, internet access, IT personnel, and digital content development. While the Education and Training Policy attributes the limited use of ICT to a "shortage of equipment and human resources in teaching ICT" (MoEST, 2023, p. 45), this study demonstrates that teachers' deeply held beliefs can also act as significant barriers to ICT adoption in teaching and learning. Therefore, policy interventions should focus not only on removing structural barriers but also on transforming teachers' pre-existing dispositions towards ICT integration. We argue that the successful adoption of ICT in science and mathematics education will be determined by both improved contextual conditions and teachers' positive beliefs about ICT use as a pedagogical tool.

Transforming teachers' beliefs about ICT use in teaching requires continuous professional development that challenges their pre-existing misconceptions while enhancing their confidence and technical skills. It is recommended that the Ministry of Education, Science and Technology, in collaboration with development partners, implement mandatory initial and in-service training to reinforce teachers' positive beliefs about the adoption of technology in science and mathematics teaching. Moreover, mentorship arrangements combined with hands-on training should be established to provide science and mathematics teachers with opportunities to use technology in their own learning with the support of experienced peers, thereby building their confidence and competence. Future researchers are encouraged to explore additional variables beyond PU, PEU, SN, FC and TC, as teachers' beliefs may be influenced by personal characteristics such as gender, years of study, teaching experience, and subject domain (Beck et al., 2000). Likewise, using fewer than five question items per observed variable can lead to identification issues unless a pooled CFA approach is applied. However, these recommendations remain largely theoretical and require further empirical investigation to validate their efficacy in shaping teachers' beliefs about ICT use. This presents a critical gap for future research to address.

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Bridging the Digital Divide: Mathematics Teachers' Perceptions and Use of Information and Communication Technologies in the Classroom at Secondary Schools in Tanzania

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Abstract

This research investigated the perceptions of lower secondary school mathematics teachers regarding the use of Information and Communication Technology (ICT) in instruction. Ten ordinary secondary schools from Dar es Salaam and five from the Coastal regions were involved in the study. The schools were chosen based on their Mathematics Grade Point Average (GPA) from the 2021 Form Four National examinations. The research used a mixed methods approach whereby data were gathered through semi-structured interviews and questionnaires. Data were analysed using the SPSS IBM 25 software. Drawing upon the Technology Acceptance Model (TAM), it was deduced that teachers' perceptions of the usefulness and user-friendliness of ICT tools played a significant role in their adoption. Therefore, this study recommends collaborative efforts between policymakers and educators to fully leverage the benefits of integrating ICTs in mathematics education, ultimately serving both mathematics teachers and students for enhancing teaching and learning processes and quality of education.

Keywords: *ICT integration, teacher's perceptions, mathematics education, technology acceptance model (TAM), ordinary-level secondary schools, Tanzania*

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Introduction

While the Tanzanian government has made various efforts to improve the standard of Mathematics education, many students continue to struggle with underperformance in the subject. Recent data from the Basic Education Statistics-Tanzania (BEST) report of 2021 of the United Republic of Tanzania (URT) (URT, 2022) highlights this paradoxical trend; while Mathematics enjoys the most favourable student-to-book ratio in Tanzanian schools. It concurrently reports the highest failure rate when juxtaposed against other subjects. National Examination Council of Tanzania (NECTA) results of the Certificate of Secondary Education Examination (CSEE), from 2019-2020 (URT, 2021) further substantiate this concern, revealing that while subjects like Kiswahili and Chemistry boasted pass rates of 94.8% and 87.1% respectively in 2020, Basic Mathematics lagged distressingly behind at a mere 20.1%. This discrepancy persists even though, as of 2021, Mathematics textbooks outnumbered those of any other subject across both lower and upper secondary school levels (URT, 2021). Moving forward to 2022, the trend remains worrisome. A staggering 84.4% of students who took the Form Two examinations in 2022 received an 'F' grade in Mathematics, with other science subjects similarly reflecting suboptimal performances (NECTA, 2023).

Among the reasons cited for these outcomes are insufficient teaching skills among Mathematics educators and a pervasive lack of student motivation in the subject (Mazana et. Al., 2020). In the context of Tanzanian secondary schools, especially within the subject of mathematics, the potential of Information and Communication Technology (ICT) to transform educational outcomes is substantial. Through visual aids and interactive platforms, ICT can significantly deepen students' understanding. However, this transformation's success largely hinges on the teachers. The way teachers perceive the use of ICT and their willingness to harness its capabilities in mathematics is vital in revitalizing the educational landscape and boosting student performance. In Tanzanian secondary schools, the integration of Information and Communication Technology (ICT) into mathematics education presents both opportunities and challenges. Teachers are at the forefront of determining how ICT aligns with the current curriculum and whether it complements the primary objectives of mathematics instruction. Their perceptions of ICT not only reflect their understanding of its advantages and drawbacks but also reveal their profound appreciation of its significant role in pedagogy (Adhikari, 2021, Kamau et al., 2016, Mwei, 2020).

Within the realm of mathematics education, ICT introduces a mix of hope and caution. While technology offers tools that can deepen understanding and enhance teaching methods, its adoption isn't automatic. The reservations stem from various concerns, making it essential to understand how mathematics teachers perceive and respond to the idea of integrating technology. A multitude of factors such as personal teaching experiences, professional development opportunities, familiarity with technology, and the unique nuances of the Tanzanian education system shape the perceptions of teachers towards integrating technology in mathematics instruction. The Technology Acceptance Model (TAM) postulates that the perceived usefulness and perceived ease of use are pivotal determinants in technology adoption within educational settings (Davis, 1989). This means that for a country like Tanzania, where digital infrastructure is still evolving, the successful implementation of ICT in secondary school mathematics education hinges on understanding teachers' perceptions of usefulness and of easy to use. Understanding these perceptions is fundamental for its successful integration. As teachers continue to evolve through learning and exposure, too can their perceptions. The true success of integrating technology in the classroom depends not only on these evolving perceptions but also on a solid understanding of its educational value. Teachers' preparedness for ICT integration is pivotal for its successful implementation. Therefore, the transition towards using technology in the classroom must be anchored in a profound understanding of its educational potential, rather than being driven by fleeting trends.

Background to the Study

In the evolving realm of education, teachers' attitudes toward technology play a crucial role in its successful integration (Teo et al., 2016). While there is a significant potential in integrating ICT into mathematics education, the success of such initiatives depends on the perceptions, training, and support provided to teachers. For optimal outcomes, a balanced approach, combining the strengths of traditional methods with the advantages of technology, is often recommended. Several researchers have previously embarked on the exploration of teachers' attitudes toward technology integration, each with distinct facets and approaches. Teo et al. (2016), Venkatesh et al. (2016), and Schlebusch (2018), for instance, have their unique methodologies and focal points in examining this phenomenon. Tuncer (2012) offers valuable insights into the integration of technology in classrooms, emphasizing the pivotal role of teachers' attitudes in this process. Despite positive attitudes toward technology, some teachers restrict students' access to it, even when they show strong motivation for its use. This disparity between attitude and practice presents a significant ongoing challenge in education as evidenced by comprehensive studies by Bamigboye et al. (2013), Chou (1997), and Christensen (2002), it's crucial to discern the nuances in each study.

Several assessment scales have also been curated to evaluate these attitudes, as seen in the works of Agyei and Voogt (2010) and Christensen and Knezek (2009). Yet, these scales are not monolithic. Some lean heavily into dissecting elements such as enjoyment and anxiety, while others might prioritise different criteria. The range in the number of criteria further accentuates the variability among studies. For instance, while Christensen (2002) delves deep with nine criteria, both Bamigboye et al. (2013) and Chou (1997) streamline their approaches with just four. Within the Tanzanian educational framework, various studies have also illuminated distinct facets of ICT integration. For instance, Kafyulilo (2014) delved into the specific realm of mobile phones, focusing on their access, usage, and implications as learning tools in teaching. Kisanga and Ireson (2016), on the other hand, concentrated on the development of a scale assessing e-learning-related attitudes, gravitating more towards the online educational sphere. Building on these foundational studies, Njiku (2022) offers a novel perspective by examining the perceptions related to the application of ICT explicitly in mathematics teaching at the secondary level. The study done by Mwalongo (2011) adopted a more encompassing approach, exploring teachers' perceptions of ICT not just in teaching, but also for professional development and administrative purposes. Contrasting these works, Njiku et al. (2019) probed into the emotional and behavioural intricacies of teachers' attitudes toward ICT. Each of these investigations offers valuable insights, shedding light on different components of the ICT mosaic in Tanzanian education.

Contrary to the studies mentioned earlier, our current research distinctively focuses on the cognitive dimension of teachers' engagement with ICT, emphasizing their perceptions. However, focusing solely on attitudes may overlook deeper cognitive processes. While attitudes represent emotional inclinations, perceptions encompass an informed awareness of a subject. Perception encompasses how teachers interpret and understand the role of technology, providing a richer understanding of their receptivity to it (Tuncer, 2012). For instance, a teacher's scepticism about technological tools might stem from past failures or a lack of awareness of their benefits. Addressing these perceptions through training and exposure ensures that technology adoption is based on informed choices, rather than transient emotions. In essence, for robust technological integration in education, especially in Tanzanian mathematics classrooms, it is crucial to align positive attitudes with well-informed perceptions.

While earlier research provides critical insights into attitudes and related metrics, this study explores perception, primarily how these teachers cognitively grasp the potential benefits, challenges, or significance of ICT and its implications within their unique teaching contexts. Significantly, this research differentiates itself by enhancing perceptions linked to ICT use in the specific context of secondary school mathematics. Hence, despite the invaluable insights of previous studies, this research distinguishes itself by blending a focus on both perception and mathematics, adding a refined perspective to the dialogue on ICT in Tanzanian education (Kayombo and Mlyakado, 2016; Mwila, 2018).

Research questions

The study was guided by four research questions:

i. How do mathematics teachers perceive their ability to use ICT tools in teaching Mathematical concepts in the classroom setting?
ii. To what extent do teachers use ICT to achieve Secondary school mathematics objectives?
iii. Which learning objectives do Mathematics teachers believe are the best achieved with the use of ICT tools?
iv. What challenges do teachers face in integrating ICT tools into their mathematics instruction?

Literature Review and Theoretical Framework

Literature review

The role of teacher perception in ICT integration in Mathematics education

The fusion of ICT into mathematics potentially simplifies complex concepts, engages students more deeply, and caters to diverse learning needs, ensuring a more holistic and effective educational experience (Das, 2019; Mistretta, 2005; Mwaniki et al. 2024). The confluence of perception, ICT, and mathematics forms a dynamic triad in the educational landscape. Perception, in this context, refers to the way teachers interpret, understand, and feel about the role of ICT in teaching mathematics. Teacher's perception encompasses both their cognitive understanding and emotional response to the integration of technology into their teaching practices (Das, 2019; Shar 2022; Mwaniki, 2024). Understanding teachers' perspectives and addressing systemic issues are crucial for ensuring that ICT realises its full potential in enhancing mathematics education. For successful integration, fostering positive perceptions among educators is crucial, as their attitudes will significantly influence the acceptance and effectiveness of ICT tools in the mathematics classroom.

Determinants and factors shaping teachers' perceptions

Understanding the determinants that shape an educator's stance on ICT in mathematics is crucial. At its core, the perception of ICT doesn't solely rest on its educational merits. Some view it as a combination of elements such as liking technology, feeling its importance, and having comfort using it (Njiku et al., 2019). An educator's perspective on the role of ICT in teaching mathematics is influenced by various factors. Training and exposure to ICT play a major role in shaping these perceptions. According to Wong and Li (2008) and Mwei (2020), younger educators who are familiar with the digital environment might be more inclined to incorporate technology compared to their older peers. The support from educational institutions, both in terms of resources and training can also impact the integration of ICT. Additionally, personal teaching philosophies, whether traditional or more modern, can influence an educator's stance on ICT. The environment within an educational institution is another pivotal determinant. If there is robust infrastructural and pedagogical support, educators are more likely to be receptive to the use of ICT in their classrooms (Wong, 2008). On the flip side, a lack of resources or support might deter its adoption. Additionally, the integration of ICT in mathematics teaching offers several potential benefits yet its effectiveness largely depends on how educators perceive its role, the support they receive, and the broader teaching environment (Davis, 1989).

The benefits of ICT integration in Mathematics instruction

Educators acknowledge the numerous advantages of integrating ICT into mathematics instruction. Tools such as graphing calculators and specialised software simplify complex mathematical concepts for students, while interactive tools and educational games enhance student engagement in learning (Wong, 2008, Bingimlas, 2015). Moreover, some ICT tools adjust according to individual student needs, ensuring more tailored learning experiences by enabling instant feedback, and helping students understand and adjust their learning process (Miima, 2013).

Challenges and concerns in the integration of ICTs

The integration of ICT in Mathematics education is not without its challenges. Some educators express concerns over students becoming too reliant on technology, possibly undermining their foundational mathematical skills. Unequal access to technology among students might lead to disparities in learning opportunities. Not all educators are well-versed in technology, indicating a need for consistent training (Maja 2023; Abel, Tondeur and Sang 2022; Ndume, Kisanga, and Majige 2021; Malekani 2018; Kisanga 2016). There's also the financial aspect to consider, as obtaining the necessary technological tools can be expensive. Furthermore, the potential for distractions in the online realm can divert students from their primary learning goals (Vimbai, Kennedy, and Tendayi, 2013).

Theoretical framework: Technology Acceptance Model (TAM)

The digital era's evolving landscape of mathematics education necessitates a profound theoretical foundation to decipher teacher perceptions and inclinations towards ICTs. The TAM, devised by Davis in 1986, serves as an apt lens to illuminate these dimensions, especially in the context of mathematics educators (Hsu et al., 2013; Mugo et al., 2017). TAM suggests that an individual's intention to use technology is shaped by its perceived usefulness and ease of use, which subsequently affects the actual system use. This model is ideal for examining teachers' readiness to incorporate ICT tools into their teaching, reflecting on their perceptions of these tools' usefulness and user-friendliness. TAM provides a framework for analysing teachers' perceptions, challenges, and motivations regarding ICT tool utilisation in Tanzanian secondary school mathematics classrooms (Mugo et al., 2017).

At the heart of TAM, there are two pivotal constructs: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). PU gauges users' belief that using a specific technology will enhance their performance. In the context of this study, this aligns with the first research question inquiring how mathematics teachers perceive the potential of ICT tools in enhancing student understanding and engagement. As the study delves into the question of ICT's role in simplifying the teaching of intricate mathematical concepts, TAM steers the inquiry towards the PU construct. A heightened PU indicates that teachers discern a notable advantage in student outcomes due to ICT integration. Yet, recognizing a tool's potential doesn't always lead to its adoption. Here, PEOU comes to the fore, assessing the anticipated ease or complexity of using the technology.

The second research question, probing the relationship between teaching experience and ICT tool adoption, interacts with both PU and PEOU. Newer teachers, even when recognizing ICT's benefits (elevated PU), might hesitate if they anticipate a steep learning curve, suggesting a lowered PEOU. In contrast, experienced educators might be sceptical about ICT's advantages, reflecting a subdued PU. However, if the tools appear user-friendly, even those with traditional pedagogical approaches might be swayed, highlighting PEOU's role. The third research question, which zeroes in on the challenges that hamper the seamless integration of mathematics teaching with ICT tools, positions PEOU as a focal construct. If educators, despite seeing the myriad benefits of ICT (robust PU), are restrained by challenges like insufficient training, limited resources, or the inherent complexity of some tools, it underscores a subdued PEOU. In summary, the Technology Acceptance Model provides an insightful framework to unravel the complex dynamics of mathematics teachers' perceptions and behaviours towards ICT tools. TAM's core constructs – PU and PEOU – offer valuable perspectives that enrich the research questions, facilitating a deeper dive into the motivators and barriers influencing ICT adoption in the mathematics realm.

Research Methodology

A case study design was adopted to investigate the teachers' perceptions of the use of ICT tools during teaching. The section elucidates the strategies and procedures that were used to gather and analyse the data pertinent to the research questions, grounded in TAM that offers a holistic view of the factors influencing the acceptance and integration of ICT. The mixed-methods approach ensures that both statistical data and in-depth perspectives are harnessed for a comprehensive analysis (Leavy, 2022, Weyant, 2022). To serve this purpose, the study employed a mixed-methods approach, combining both quantitative and qualitative data to gain a comprehensive understanding of the topic. This method is beneficial as it triangulates data sources, ensuring the reliability and validity of the results.

Due to financial constraints, the population for this study comprised secondary school teachers from two regions, Dar es Salaam and the Coastal region. The schools were selected based on two criteria, the grade point average (GPA) on basic mathematics for the national certificate of secondary education examination results of the year 2021 that ranged from 1.3 to 3.5 inclusively and the type of schools. Using a stratified random sampling based on the criteria set to ensure a representative sample that considers two regions, only 10 secondary schools from Dar es Salaam and 5 from the Coastal region met the selection criteria. A total of 57 mathematics teachers from those schools participated in the study. However, due to the lack of a considered GPA range, not all districts had schools qualified to be in the sample. Among the selected secondary schools, 2 were girls' secondary schools, 3 boys' secondary schools and 10 were co-education secondary schools. The chosen Secondary schools from Dar es Salaam that met a GPA of 1.3 to 3.5 were Bright Future (co), Chang'ombe Demonstrations (co), Helasita (co), Feza Boys, Feza Girls, Kibasila (co), Canosa (co), Liberman (boys' school), St. Augustine Tagaste (co) and Shamsiye (boys' school). Secondary schools in the Coastal region were Baobab Secondary School (co), Kibaha (boys' school), Marian boys, Marian girls, and Gili (girls' school). During data collection, it was noted that out of 57 participant teachers, four (4) were female lower secondary school teachers and fifty-three (53) were male lower secondary school teachers, aged between 23 and 51 years. At a minimum, each teacher had two years of experience teaching mathematics, and the majority held a bachelor's degree. Among the selected secondary schools, eleven (11) reported the presence of computer labs whilst projectors were commonly found as ICT tools across all of the selected schools. Table 1 shows the sample of the schools qualified for the study with their respective GPA obtained in national form four, certificate of secondary education examination results in the year 2020.

Table 1

Mathematics Grade Point Average of The Schools at the National Examination (CSEE Results, 2020).

S/No.	Name of School	GPA	Subject rank	Region
1,	Bright future	1.3789	6	Dar es Salaam
2	Canosa	1.4831	9	Dar es Salaam
3	Chang'ombe	2.9	130	Dar es Salaam
4	Feza girls	1.6667	11	Dar es Salaam
5	Feza boys	1.46	8	Dar es Salaam
6	Helasita	2.8222	105	Dar es Salaam
7	Kibasila	2.8341	108	Dar es Salaam
8	St. Augustine Tagaste	2.1887	33	Dar es Salaam
9	Liberman Boys	3.1395	172	Dar es Salaam
10	Shamsiye	1.8	18	Dar es Salaam
11	Baobao	3.5147	317	Coastal Region
12	Gili	2.4666	57	Coastal Region
13	Kibaha boys	2.0667	26	Coastal Region
14	Marian girls	2.5472	67	Coastal Region
15	Marian boys	1.4532	7	Coastal Region

After obtaining the necessary permissions from the University of Dar es Salaam, districts (Ilala, Temake and Kinondoni) and Coastal region authorities, questionnaires were then distributed to the sampled schools using KOBO. A structured questionnaire based on the TAM was administered to all mathematics teachers in schools under a controlled environment to ensure the reliability of responses. The questionnaire comprised demographic details, ICT attitudes and perceptions, and perceived ease of use and perceived usefulness of ICT. Thereafter, the semi-structured interviews were conducted with teachers to gain in-depth insights into their experiences and perspectives on ICT integration while teaching mathematics lessons. The interviews revolved around the challenges faced, the perceived benefits of ICT, and the factors influencing their adoption of ICT in teaching mathematics. The instruments were piloted and tested on a smaller sample before the main survey. Cronbach's alpha was used to measure the reliability of the questionnaires, ensuring internal consistency. The feedback from the pilot study was used to refine and improve the instrument for data collection.

Data Analysis

Quantitative data from the questionnaires were analysed using SPSS IBM 25 software. Descriptive statistics, correlation and regression analyses were used to interpret the data concerning the research objectives. Qualitative data from the interviews were transcribed and then subjected to thematic analysis. This allowed the identification of key themes and patterns regarding teachers' experiences and perceptions towards ICT integration. The qualitative and quantitative data are presented in Table 2, Table 3, Table 4 and Figure 1.

Ethical Considerations

Researchers obtained research clearance from the University of Dar es Salaam, which introduced them to the relevant local education authorities, including regional and district education officers in Ilala, Kinondoni, and Temeke, as well as Heads of Secondary Schools. The permits granted by regional and district authorities allowed researchers to conduct the study in selected secondary schools. Informed consent was obtained from all participants before data collection, ensuring they were aware of the voluntary nature of participation and the confidentiality of their responses. All data were anonymised during analysis to protect participants' privacy.

Findings

Perception of mathematics teachers on the ability to use ICT tools in teaching mathematical concepts in the classroom setting

In light of the TAM theory, understanding users' perceptions, particularly educators in this instance is paramount to predicting and explaining system usage. The findings in Table 2 highlighted in this research accentuate distinct patterns and tendencies in teachers' perceptions towards employing ICT tools to convey various mathematical topics.

Table 2

Means, Standard Deviations, and Percentages Showing the Extent of Teachers on the Use of ICT Tools on the Subject Emphasis

No	Item	Mean	Std. Deviation	Per cent	Rank	Extent
	Computational techniques	2.68	1.212	53.60	8	Fairly
	Specific mathematics or definitions	3.14	1.109	62.80	5	Fairly
	Broad mathematics concepts	3.16	1.162	63.20	4	Fairly
	Problem-solving/inquiry skills	3.11	1.080	62.20	7	Fairly

	Skill in communicating in speech or writing about mathematical ideas or applications	3.12	1.166	62.40	6	Fairly
	Importance of mathematics in daily life	3.81	1.093	76.20	1	Frequently
	Applications of mathematics in science	3.79	0.977	75.80	2	Frequently
	Applications of mathematics in business and industry	3.63	1.080	72.60	3	Frequently

Relevance of mathematics in real-world contexts

Teachers feel particularly confident and inclined to utilise ICT tools when elucidating the real-world importance and applications of mathematics. This is evident from the high percentages (above 70%) corresponding to topics like the significance of mathematics in daily life, its applications in science, and its use in business and industry. This might be attributed to the inherent interactive and illustrative nature of digital tools, which can effectively contextualise mathematical concepts in real-life scenarios. Such content often requires visual aids, simulations, or practical examples, all of which can be efficiently provided by ICT. This correlation supports the TAM's "Perceived Usefulness" (PU) construct, suggesting that teachers see a tangible benefit in leveraging ICT tools for these specific topics.

Fundamental mathematical concepts and techniques

There's a noticeable dip in confidence when it comes to deploying ICT for more foundational aspects of mathematics. As observed, only around 53% to 63% of teachers believe they can use ICT tools effectively to teach computational techniques, broad mathematical concepts, problem-solving skills, and skills in communicating mathematical ideas. These findings resonate with the "Perceived Ease of Use" (PEOU) construct in TAM. It suggests that while teachers may recognise the potential benefits of integrating ICT tools (PU), they might perceive foundational topics as being more challenging to teach through digital platforms or feel less equipped or trained to do so effectively. The standard deviation values, especially the 1.212 for computational techniques, further reinforce this notion, indicating a larger variance in teachers' perceptions regarding the ease of use of ICT tools for such topics. Furthermore, the rankings can be interpreted as a direct reflection of teachers' comfort levels, with foundational topics ranking lower (items 1 to 5) and application-based topics securing the top ranks (items 6 to 8). The rankings underscore the areas where potential interventions like targeted ICT training, could be most beneficial for educators.

How does teaching experience influence the choice and use of ICT tools and mathematical packages among mathematics teachers?

Table 3 shows the perception of mathematics teachers on their ability to use ICT tools and mathematical packages among the teachers based on their teaching experience. Given the findings presented in Table 3, which details the use of ICT tools and mathematical packages among teachers based on their teaching experience, several insights emerge in line with the Technology Acceptance Model (TAM). The findings show that novice teachers use more technological software followed by experienced teachers. The intermediate teachers are the least users of the technology in teaching different concepts of mathematics in the classroom.

Table 3

ICT Tools and Mathematical Packages Usage Against Teachers' Experience

Percentages and Totals are Based on Respondents in a Dichotomy Group Tabulated at Value 1.						
			Experience Groups			
Novice Intermediate			**Experienced/ Expert**			**Total**
Tools/ Mathematical Package	Matlab	Count	4	1	5	10
	Graphing Calculator 3D	Count	4	0	3	7
	SPSS	Count	2	2	2	6
	Geogebra	Count	5	1	3	9
	Graph Sketch	Count	6	4	4	14
	Microsoft Mathematics	Count	5	6	2	13
	Maths Editor	Count	3	1	3	7
	Graph Maker	Count	2	2	3	7
	Internet Archive	Count	3	1	1	5
	None	Count	6	7	7	20
	Others	Count	21	2	5	28
Total		Respondents	61	27	38	126

Perceived usefulness and teaching experience

There is a diverse use of technological tools among mathematics teachers. Notably, Graph Sketch (11%), Microsoft Mathematics (10%), and Matlab (7.9%) are the most popular among teachers, highlighting the perceived usefulness of these tools in their teaching regimen. Yet, a significant 16% reported not using any tool. This absence, especially when juxtaposed with the prominence of certain tools, signals the possibility that there may be varying levels of perceived usefulness across the faculty – an essential construct of TAM.

Perceived ease of use versus experience

Delving deeper into the experience-wise breakdown, novice teachers seem to have a broader spread in their tool adoption, from the use of GeoGebra, and Graph Sketch, to Microsoft Mathematics. This suggests that newer entrants to the teaching profession might be more open to experimenting with diverse tools, likely due to their recent exposure to these during their training or their inherent comfort with technology. However, the fact that even among the novice group, there's a noticeable percentage that hasn't adopted any tool indicates potential challenges in perceived ease of use or perhaps lack of access and training.

Experienced teachers and tool adoption

The expert or experienced teacher group demonstrates a preference for tools like Graph Sketch but shows less inclination toward Microsoft Mathematics. This suggests that entrenched teaching habits or a perceived lack of added value may influence their adoption patterns.

Diverse tools and potential barriers

The 'Others' category, which stands at 22%, points towards a plethora of other tools that haven't been specified. This indicates that while there's a wide range of tools available, there might be barriers (either in terms of ease of use or perceived utility) preventing a more uniform adoption across the board. In light of the TAM theory, these findings underscore the pivotal role that both perceived usefulness and perceived ease of use play in the adoption of ICT tools among mathematics teachers. Further, the dichotomy based on teaching experience accentuates that these perceptions are dynamic and can evolve based on the teacher's tenure and the evolving technological landscape. Consequently, targeted interventions, perhaps in the form of training or workshops, might be needed to bridge these perception gaps and foster a more inclusive adoption of ICT tools across all experience levels.

The extent to which teachers use ICT tools to achieve various mathematical packages

Considering the Technology Acceptance Model (TAM) in the interpretation of the data concerning the research question, "How extensively do teachers use ICT tools to achieve various mathematical packages?" it is clear that the two primary determinants of TAM, namely Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), manifest differently across experience levels in teachers' recognition and potential application of ICT tools.

Given the data from Table 4 and Figure 1, teachers have demonstrated a clear inclination toward using ICT tools when explaining the real-world significance of mathematics. The importance of mathematics in daily life is ranked first with a high mean of 3.81 and 76.2% of teachers emphasizing its use. Similarly, applications of mathematics in science, business, and industry are highlighted by over 70% of teachers, further underscoring the perceived usefulness of ICT tools in these areas. Among universally acknowledged tools like Matlab, Mathematica, and Microsoft Mathematics, usage rates stand at 11%, 10%, and 9.4%, respectively. This suggests that these tools are perceived as useful (PU) across all experience groups. Their widespread recognition indicates that they offer essential functionalities for mathematics teaching, making them indispensable for many educators.

Conversely, computational techniques, despite being a core component of mathematics, are ranked the lowest with a mean of 2.68. Only 53.6% of teachers believe they can effectively employ ICT tools for this foundational topic. This suggests a potential gap in either available ICT resources for these topics or teachers' comfort and training in applying them. Other foundational topics, including specific mathematics definitions and broad mathematics concepts, hover in the 60% range, reflecting moderate confidence in using ICT tools. Furthermore, the standard deviation values, especially the higher value of 1.212 for computational techniques, indicate a greater variance in teachers' perceptions. This implies that while some educators might be adept at using ICT tools for these foundational aspects, a significant portion may feel unsure or untrained. Incorporating these specific data points into our interpretation, it becomes evident that while teachers value the potential of ICT tools, especially for real-world contextual teaching, there's a palpable need for enhanced training and resources focused on foundational mathematical aspects. Addressing these gaps can catalyze a more comprehensive and effective integration of ICT tools in mathematics instruction.

Table 4

ICT Tools Used by Teachers in Teaching Various Mathematical Packages Knowledge and Experience Groups Crosstabulation

Novice Intermediate			experience groups			Total
			Experience/ Expert			
ICT tools used for teaching Mathematics	Matlab	Count	9	9	10	28
	Maple	Count	5	6	3	14
	Mathematica	Count	6	9	11	26
	Graphing Calculator 3D	Count	11	5	7	23
	Geogebra	Count	7	5	8	20
	Graph Sketch	Count	9	7	6	22
	Microsoft Mathematics	Count	7	11	6	24
	Maths Editor	Count	6	7	8	21
	Graph Maker	Count	3	6	5	14
	Others	count	10	31	23	64
Total		Count	73	96	87	256

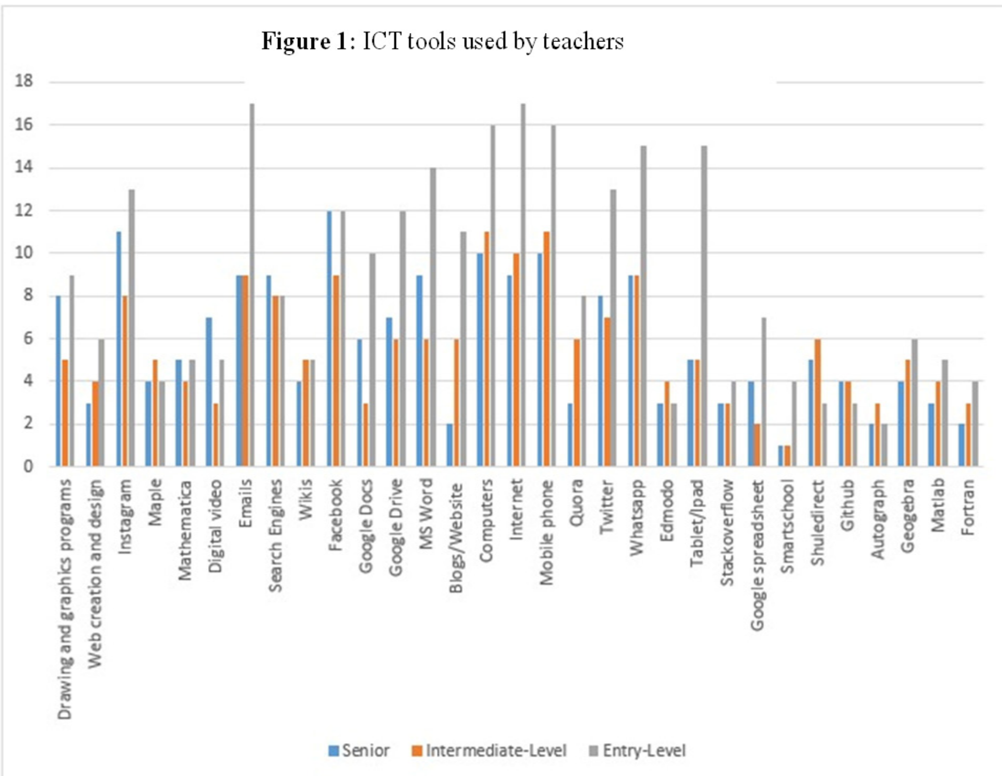

Figure 1: *ICT tools used by teachers*

Challenges teachers face in integrating ICT tools into their mathematics instruction

In addition to quantitative findings, a second set of results was obtained from the focused group, which helped to contextualise and interpret the quantitative results. Firstly, the majority of users believe that ICT can simplify delivering a lesson to students, help to explain complex ideas and mathematics topics, reduce the time taken to deliver a lesson, and can also allow for flexibility during teaching. For example, a teacher from one school pointed out:

> "… We plan to build a digital centre because the current computer lab offers limited access to students…" another said:

> "… What we are supposed to do is to cope, adapt and use technology for us to reach to do better. And for our school, we have to provide more than two computers to our teachers…"

Secondly, teachers think the use of ICT to teach mathematics may affect the ability of students to solve mathematics problems as well as reduce the performance of students in examinations. The following were the main challenges explained by the respondents:

Inconsistent internet connectivity

Reliable internet bandwidth remains an issue, particularly outside the Dar es Salaam region. For instance, a respondent said:

> "…I believe that using ICT tools to teach mathematics, especially the challenging topics like Three Dimension and Sphere can enhance the understanding of students for with computer becomes very easy and flexible to teach, but the internet connectivity in peripheral parts of the country is still a challenging phenomenon …"

Limited technical support

While students are acquainted with the use of ICT tools in the classroom, the absence of immediate technical assistance when issues arise poses a problem. Teachers often find themselves tasked with troubleshooting during lesson hours. Another said:

> "…when I taught using ICT the students were interested and reduced the time I used to explain and still students understood the lesson very well, but very small part of the content can be effectively covered…"

Unavailability of essential mathematical software

Many computers lack the necessary mathematical packages installed, hindering effective ICT integration in mathematics teaching. The majority of the teachers thought it entails training students on how to use the ICT tools to participate in the lesson. For example, a teacher said:

> "… Mathematics is among challenging subjects that are very cumbersome to teach using ICT tools as teachers are not computer speciality…"

Time constraints versus ICT utilisation

Despite possessing the skills to use ICT tools, their integration can be time-intensive. Given the stringent syllabus timelines and no provision for extra hours, many educators find it challenging to incorporate these tools efficiently. For instance, one respondent said:

> "…I imagine the use of ICT going to inhibit the ability of students in solving present solution of questions and hence reducing the number of students passing mathematics in the national examination…"

Another said:

> "…when I taught using ICT the students were interested and reduced the time I used to explain and still students understood the lesson very well, but very small part of the content can be effectively covered…"

A mismatch between student enthusiasm and curriculum rigidity

While students exhibit a keen interest in ICT-driven learning, the current curriculum offers limited flexibility. There's a distinct lack of training tailored for the application of ICT in mathematics teaching, and the curriculum doesn't explicitly outline mandatory ICT-based learning modules for students. Moreover, the results from the discussion show that teachers need software tools for teaching mathematics, training on how to construct content and use software, as well as support. Several respondents said:

> "…The computer lab with working computers is available, but not enough software for teaching mathematics installed…"

In addition, there was a misconception of the meaning of "to use ICT tools to teach mathematics".

The majority of the teachers thought it entails training students on how to use the ICT tools to participate in the lesson. For example, a teacher said:

> "…Mathematics is among challenging subjects that are very cumbersome to teach using ICT tools as teachers are not computer speciality…"

Discussion of the Findings

The integration of tools in mathematics instruction within Tanzania's secondary schools stands as a testament to the evolving landscape of modern education (Das, 2019; Josh, 2017; Sawyerr A, Agyei D, 2022). This study underscored the vibrant potential of ICT tools in enriching the teaching and learning experience, especially in making mathematical concepts more relatable and applicable to real-world scenarios. However, alongside the promise lies a gamut of challenges, from infrastructural limitations to discrepancies in teaching methodologies rooted in experience. The TAM aptly frames these findings, suggesting that perceptions of usefulness and ease of use are pivotal in determining ICT adoption. The disparity in tool utilisation among educators, based on tenure, underscores the pressing need for a unified approach to professional development and resource allocation. Moreover, the challenges spotlighted, notably the lack of consistent internet connectivity, absence of vital mathematical software, and curriculum rigidity, necessitate immediate and concerted efforts from educational stakeholders. Collaborative endeavours that bridge the gaps between policymakers, educators, and technical experts could usher in a new era of ICT-integrated mathematics instruction in Tanzania. As we forge ahead into an increasingly digital future, ensuring that our educators are well-equipped and our curriculum is adaptive remains paramount. Only then can we truly harness the transformative power of ICT for the benefit of our students and the broader educational ecosystem. The study recommends the following:

First and foremost is infrastructure development. Addressing the digital divide requires a concerted effort to enhance technological infrastructure in less developed regions. This can be achieved through collaborations among local governments, educational institutions, and private enterprises. By working in tandem, these stakeholders can accelerate the provision of reliable internet services, bridging the gap between urban and remote educational settings.

Furthermore, as technology permeates classrooms, the inevitability of technical glitches arises. To mitigate disruptions and ensure smooth lesson delivery, institutions should prioritise establishing dedicated technical support. Whether this entails creating specialised teams or training existing staff members, the goal is to empower educators to concentrate on their core teaching responsibilities, confident in the knowledge that any ICT-related hiccups can be swiftly addressed.

In parallel, the maintenance of the technology tools in play is paramount. Ensuring that essential mathematical software on school computers undergoes regular checks and updates can guarantee that the academic community has access to relevant, functioning tools. In this realm, strategic collaborations or partnerships with software vendors can be explored. Such alliances might offer educational institutions discounted or even complimentary access to pivotal educational software packages.

In addition to the technological considerations, the educational content—the curriculum—must not be static. Periodic reviews and updates by educational authorities will ascertain that the content remains in step with technological progress. Such proactive measures would grant teachers the latitude to seamlessly weave beneficial ICT tools into their lessons, free from undue time constraints.

Lastly, the role of educators in this digital evolution cannot be underestimated. To optimise the benefits of ICT, teachers must be adept at leveraging these tools. This necessitates continuous training and professional development tailored to the nuances of ICT in mathematics instruction. By consistently enhancing educators' proficiency in this domain and revisiting the curriculum to articulate ICT-centric modules, we can set the stage for a structured, clear, and enriched learning journey for students.

Conclusion and Recommendations

Conclusions

The integration of ICTs in mathematics instruction within Tanzania's secondary schools stands as a testament to the evolving landscape of modern education. This study underscored the vibrant potential of ICT tools in enriching the teaching and learning experience, especially in making mathematical concepts more relatable and applicable to real-world scenarios. However, alongside the promise lies a range of challenges, from infrastructural limitations to discrepancies in teaching methodologies rooted in experience. The TAM aptly frames these findings, suggesting that perceptions of usefulness and ease of use are pivotal in determining ICT adoption. The disparity in tool utilisation among educators, based on tenure, underscores the pressing need for a unified approach to professional development and resource allocation. Moreover, the challenges spotlighted, notably the lack of consistent internet connectivity, absence of vital mathematical software, and curriculum rigidity, necessitate immediate and concerted efforts from educational stakeholders. Collaborative endeavours that bridge the gaps between policymakers, educators, and technical experts could usher in a new era of ICT-integrated mathematics instruction in Tanzania. As we forge ahead into an increasingly digital future, ensuring that our educators are well-equipped and our curriculum is adaptive remains paramount. Only then can we truly harness the transformative power of ICT for the benefit of our students and the broader educational ecosystem.

Recommendation for actions

Based on the findings concerning teachers' perceptions of the ability to use ICT tools in teaching mathematical concepts, the following recommendations are proposed:

i. It is evident that teachers see the value of using ICTs for real-world applications of mathematics but are less confident in their abilities to leverage these tools for foundational topics. Consequently, targeted training sessions should be initiated, focusing on integrating ICT tools into teaching computational techniques, broad mathematical concepts, and problem-solving skills. These sessions can incorporate hands-on workshops, where teachers can actively engage with the tools, facilitating a smoother transition to the digital teaching of these foundational concepts. Intermediate teachers, showing a diverse toolkit, should lead workshops to bridge the learning gap between novices and experts. A unified digital platform integrating popular tools can streamline adoption, while pilot programs can ensure effective tool integration. Establishing feedback mechanisms allows for real-time insights into tool efficacy. Emphasizing real-world applications can enhance tool adoption by underscoring their tangible benefits in mathematics education.
ii. Schools should collaborate with ICT experts to develop resources tailored to mathematics topics, ensuring the tools align with pedagogical best practices. Furthermore, continuous feedback loops should be established, allowing teachers to share their experiences, challenges, and success stories with their peers, fostering a collaborative environment that encourages more widespread adoption of ICT tools.
iii. In conclusion, from a TAM perspective, while the "Perceived Usefulness" of ICT tools is recognised across various mathematical topics, there's a discernible gap in the "Perceived Ease of Use," especially for foundational mathematical concepts. Bridging this gap would be essential for a more widespread and effective adoption of ICT tools in mathematics education.
iv. Investment in ICT infrastructure is crucial to ensure that teachers have access to the necessary resources to integrate ICT seamlessly into their teaching methodologies.

Author Contributions

All authors have contributed subsequently towards the design and writing of the manuscript. Furaha Chuma carried out the Introduction part, Literature review, and analysis and edited the manuscript. Christina Raphael worked out on the introduction and literature review and reviewed the manuscript. All authors approved the final manuscript.

Declarations

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Predictors of Students' Participation in Science and Mathematics Subjects in Tanzanian Secondary Schools

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Abstract

This study investigated the factors that predict secondary school students' participation in science and mathematics subjects in Tanzania. The data were collected from 1,382 Form 2 students sampled from sixteen public secondary schools using a validated questionnaire and focus group discussions. Data were analysed by using descriptive statistics, regression analysis, and content analysis techniques. The quantitative findings from regression analysis indicated that prior performance and teachers' instructional feedback significantly predicted students' participation in mathematics and science subjects. Also, students whose parents had higher education were more interested in science and mathematics than those whose parents had lower education. Qualitative findings showed that a shortage of teachers, textbooks, and lab equipment barred students' participation in science and mathematics subjects. The findings call for the enhancement of science and mathematics teachers' instructional and feedback practices to promote a learner-centred learning environment.

Keywords: *predictors, student participation, secondary school, science and mathematics*

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Introduction

Promoting positive attitudes toward science and mathematics has persistently drawn global attention due to its significant impact on students' learning outcomes (Kolne & Lindsay, 2020; Shojaee, 2019). The shortage of skilled workers in Science, Technology, Engineering, and Mathematics (STEM) careers has also prompted several countries to make students' participation in science and mathematics subjects right from the basic education level a priority in preparing future STEM experts (Dickerson et al., 2015). In European nations for instance, education sectors have set strategic plans for strengthening the quality of STEM education by promoting enrolment in science and technical fields (Kearney, 2011). One of these initiatives is to promote school-industry partnerships to foster students' career aspirations in STEM (Kudenko et al., 2017). Similarly, in Africa, several countries have developed strategies to increase investment in science and technology to transform their socio-economic development (Blom et al., 2016). For instance, the Tanzania Vision 2025 recognises science and technology as the main driving force meant to transform the country into a semi-industrialised middle-income economy by 2025. Likewise, the National Science and Technology Policy (URT, 1996) and the Educational and Training Policy (Ministry of Education and Vocational Training [MoEST], 2023) promote the advancement of STEM education as the driver of the country's social and economic development.

In principle, promoting students' participation in science and mathematics subjects has continued to be a priority of several governments as a means to sustain STEM professions. Participation in science and mathematics subjects would increase if most students choose to study those subjects at the basic education levels, i.e., in primary and secondary schools. At the age of 12 to 14 years, students make preliminary choices of subjects for specialization into STEM careers or other academic tracks (Tripney et al., 2010). In the Tanzanian context, students must study science and mathematics subjects such as Biology, Physics, and Chemistry during the first two years of Ordinary level (junior) secondary education (MoEVT, 2023). Then, they can opt out of some of the subjects (except for Mathematics and Biology which are compulsory subjects) while in their third year of secondary education (i.e., Form 3) at the age of 15 to 16 years. Students' choices of subjects are based on their preferences and advice from significant others (Falk et al., 2016). Apart from the perceived benefits of STEM subjects, a good number of secondary school students in Tanzania do not opt for such subjects after compulsory demands (Ndalichako & Komba, 2014). Specifically, the analysis of student enrolment and performance in national examinations (Table 1) reveals that over 75% and nearly 70% of secondary school students choose not to study Physics and Chemistry subjects, respectively, when given the option (MoEST, 2021, 2022). So, this study investigated the factors influencing secondary school students' participation (or lack thereof) in science and mathematics subjects in Tanzania.

Table 1

Enrollment, Performance, and Drop-out Rate of Optional STEM Subjects in CSEE

Subject	Year	Sat for Examinations	Passed the Examinations	Failed the Examinations	Opted-out the Subject
			Total (%)	Total (%)	Total (%)
Physics	2021	115,846	64,096 (55)	51,750 (45)	368,552 (76)
	2022	114,144	78,009 (68)	36,135 (32)	406,255 (78)
Chemistry	2021	151,118	139,054 (92)	12,064 (8)	333,280 (69)
	2022	155,007	145,215 (94)	9,792 (6)	365,392 (70)
Biology	2021	484,398	325,656 (67)	158,741 (33)	0 (0)
	2022	520,399	353,046 (68)	167,353 (32)	0 (0)
Mathematics	2021	484,439	94,677 (20)	389,761 (80)	41 (0)
	2022	520,332	104,488 (20)	415,844 (80)	67 (0)

Note. CSEE = Certificate of Secondary Education Examinations

Before making their selection of subjects, boys, and girls participating in science and mathematics subjects tend to be at par in number. A study by UNESCO (2017) in the UK found that by the age of 10 to 11 years, boys and girls participate relatively equally in STEM subjects but the proportion falls to one-third for boys and one-fifth for girls in seven years. While the available data indicates that the gender gap in students' participation in STEM subjects increases as students advance in their studies (Falk et al., 2016), the potential reasons for low participation and gender disparity are not well-known. In the Tanzanian context, the gender discrepancy in students' participation in STEM subjects emerges in Form 3 when the students make their subject choices. Here, several questions need to be addressed such as: why do most students drop STEM subjects once given a chance to make choices? Why do more girls drop STEM subjects compared to boys? These questions deserve research attention in the Tanzanian context because students' participation in science and mathematics subjects does not match the increased need for STEM experts. Also, gender disparity in participation in STEM subjects perpetuates gender disparity in access to STEM-related opportunities.

Students' participation in science and mathematics subjects

One of the strategies to understand the reasons behind students' low participation in STEM is investigating their attitudes such as interest, enjoyment, and self-efficacy in science and mathematics subjects (Tai et al., 2022). Students with positive attitudes employ more effort and persevere through challenging STEM tasks (Erol & Canbeldek, 2023), develop a deeper understanding of concepts, overcome learning challenges, and ultimately specialise in STEM-related careers (Erol & Canbeldek, 2023). Studies show that positive attitudes significantly impact student engagement and achievement (İnce, 2023; Usher & Pajares, 2009). Students' attitudes towards science and mathematics subjects vary as they advance to higher levels of education (Carr et al., 2023), and partly depend on the quality of classroom practices such as feedback-giving processes (Kyaruzi et al., 2019; Wood, 2019). However, there is mixed research evidence from which researchers can confidently formulate research hypotheses. For example, while there is substantial evidence of an association of self-efficacy with performance and persistence in STEM subjects (Erol & Canbeldek, 2023; Usher & Pajares, 2009), mixed results are reported on the role of attitude on performance (Erol & Canbelde, 2023).

The present study was guided by the self-determination theory which emphasises the role of intrinsic and extrinsic motivation in the successful completion of a task for an expected reward (Deci & Ryan, 2013). Intrinsic motivation is rooted in internal feelings (e.g., I need STEM subjects because they are good), while extrinsic motivation is a product of external drives (e.g., I need STEM subjects because they are associated with highly paying jobs) (Rosenzweig et al., 2019). Motivated students are more likely to do well in STEM subjects unlike the less motivated ones (İnce, 2023; Usher & Pajares, 2009). According to the self-determination theory, individual performance in STEM-related tasks depends on the sense of self-efficacy (autonomy), perceived high competence accumulated from previous performance, and an inclusive pedagogy in the learning process (relatedness). Accordingly, students' relatedness in terms of positive relationships with teachers, affective relationships, and feedback promotes their participation in classes and subsequent performance (Wood, 2019). For several decades, teacher feedback has been reported to have a significant effect on students' perception of their efforts and abilities (Schunk, 1984). However, the impact of feedback on students' self-efficacy and participation in learning can vary significantly depending on how it is delivered (Kyaruzi, 2019).

An investigation into student participation in STEM subjects in the Tanzanian context necessitates the analysis of gender dynamics, particularly due to the documented gender gaps in students' performance in STEM subjects. Gender consideration is also in line with the Sustainable Development Goals (SDGs) 4 and 5 which call for the promotion of equal access to quality education at all levels of education and the elimination of gender disparity in education by 2030 – including STEM subjects (UNESCO, 2017). While Dasgupta and Stout (2014) noted that the gender gap in science and mathematics performance is closing in developed countries, studies conducted in the African context show that girls still lag behind in STEM subjects (Dickerson et al., 2015) due to sociological and psychological factors among others (Matete, 2021). Conventionally, girls have been lagging behind in accessing science and mathematics education due to biased gender roles gender stereotyping, and inadequacy of school facilities (Kyaruzi, 2023; Eriksson et al., 2021). Consequently, girls' participation in science and mathematics education has been relatively lower than boys even though several policies have been implemented to address the associated barriers (UNESCO, 2017). However, research does not tell us much about why the ongoing affirmative actions have not adequately addressed gender disparities, particularly in developing countries.

Problem statement and research questions

According to the Basic Educational Statistics in Tanzania [BEST], there is low student participation in optional STEM subjects coupled with a gendered performance gap favouring male students (Ministry of Education, Science, and Technology [MoEVT], 2020). Consequently, students' poor performance in secondary schools best explains the comparatively low university enrollment in STEM-related careers (Mpehongwa, 2014).

Several studies in Tanzania (e.g., Kinyota, 2023; Matete, 2021) have addressed STEM participation at the tertiary level, while others (e.g., Kabote et al., 2014) have focused on performance and participation at the primary school level. Only a few studies (e.g., Kibona, 2023) have investigated students' participation in science and mathematics subjects at the secondary school level, which plays a critical role in supplying universities with students for future STEM professions. While previous studies provide valuable information on the problem of students' performance in STEM subjects, they have not addressed the root causes of low participation in science and mathematics. This study investigated the predictors of secondary school students' participation (or lack thereof) in science and mathematics subjects in Tanzania. Specifically, the study investigated the following research questions:

i. To what extent do students participate in secondary science and mathematics subjects in terms of mathematics attitude, science attitude, and feedback use?

ii. How much of the variance in students' participation in science and mathematics subjects can be predicted by demographic variables (primary school performance, gender, parents' socioeconomic status) and teacher feedback practices?

iii. What factors hinder secondary school students' participation in science and mathematics subjects? How could they be addressed?

Methodology

The study was conducted in sixteen secondary schools from two regions representing two geographical zones in Tanzania. In each region, stratified random sampling was used to sample two districts based on their geographical locations (i.e., urban vs. non-urban) – where one urban district and one non-urban district were selected. Then, four secondary schools were randomly selected in each of the districts. In each of the sampled secondary schools, Form 2 students were invited to participate in the study because at this class level students are about to specialise (when they enter Form 3) in either STEM-related subjects or other subjects. Participation in the study was voluntary whereby the students were asked for their consent after being informed about their rights such as the right to seek clarification, and the right to withdraw from the study at any point without any consequence. Table 2 summarises the demographic characteristics of 1,382 Form 2 students (mean age 15.6 years) who participated in the study.

Table 2

Demographics of Participating Students and Schools Split by Gender

Demographics	Female	Male	Total
Location			
Rural	393 (55.5%)	332 (49.3%)	725 (52.5%)
Urban	315 (44.5%)	342 (50.7%)	657 (47.5%)
Parents' highest education	201 (28.8%)	198(30.1%)	400 (29.5%)
Primary	324 (46.5%)	294 (43.6%)	618 (45.6%)
Secondary	74 (10.6%)	69 (10.5%)	143 (10.6%)
Diploma	30 (4.2%)	43 (6.5%)	73 (5.4%)
Bachelor degree	68 (9.6%)	54 (8.2%)	121 (8.9%)
Master's degree and above	589 (90.9%)	555 (92.5%)	1144 (91.7%)
Mothers' occupation	59 (9.1%)	45 (7.5%)	104 (8.3%)
Self-employed	525 (82.0%)	504 (82.6%)	1029 (82.3%)
Employed	115 (18.0%)	106 (17.4%)	221 (17.7%)
Fathers' occupation			
Self-employed			
Employed			

Note. Participants (%), Mean (Standard deviation)

Research design

This study employed a mixed-methods research approach. A concurrent triangulation research design was used in which the qualitative and quantitative data were collected simultaneously (Dingyloudi & Strijbos, 2018). Particularly, the study assumed a pragmatic worldview which is in line with mixed methods research. The mixed methods research approach suited the study because a combination of qualitative and quantitative data makes it possible to benefit from the strengths of each method. The qualitative component of the study enabled the researcher to gain an in-depth understanding of the factors influencing students' participation in STEM subjects through focus group discussions, meanwhile, the quantitative component helped explore students' attitudes towards participation in science and mathematics subjects by collecting data from a relatively larger sample.

Instruments

Data were collected using a questionnaire and focus group discussions with students. Quantitative data were collected using the previously validated '*Upper Elementary School and Middle/High School Student Attitudes toward STEM* (S-STEM) (Unfried et al., 2015). The feedback utility scale was also adopted from the '*Instructional Feedback Orientation Scale (IFOS)*' (King et al., 2009) to measure students' perceptions of the quality of teachers' instructional feedback. All items were adapted to a balanced six-point Likert scale ranging from 1 = Completely Disagree to 6 = Completely agree. The adopted scales were previously validated by some studies in the Tanzanian context – IFOS (Kyaruzi et al., 2019) and S-STEM (Kyaruzi et al., 2021). Other independent factors such as gender, parents' education, and prior performance were included in the questionnaire as demographic variables. Students reported their parents' or guardians' highest education level on a five-point scale from "primary education" to "master's degree and above". Parents' level of education and occupation (measured as employed or self-employed) were used as a measure of socioeconomic status. Also, students' prior performance in the Standard 7 national examinations was obtained from the National Examinations Council of Tanzania (NECTA) database using students' reported examination numbers. Table 3 summarises the scales, a sample item per scale, and the scale internal reliability Cronbach's α from the original and the present study.

Table 3

Sub-Scales, Sample Items, Mean Scores, and Estimates of Reliability

Sub-scales	Sample item	Mean (SD)	k	*Study* Cronbach's α	
				Original	*Present*
Mathematics attitude	I would consider choosing a career that uses math.	3.98 (.92)	8	0.85	0.88
Science attitude	I expect to use science when I get out of school.	4.62 (.91)	9	0.83	0.83
Mathematics Feedback Use	I feel relieved when I receive positive feedback from my Mathematics teachers.	5.03 (.84)	9	0.85	0.87
Science Feedback Use	I feel relieved when I receive positive feedback from my science teachers.	5.12 (.86)	9	0.85	.89

Note. SD = Standard deviation, k = Number of items

In addition to the questionnaire, eight focus group discussions (FGDs) were conducted with 48 students from eight sampled schools distributed into rural and urban districts. FGDs were conducted in eight out of the sixteen schools (50%) with at least one school in each district and there was equal representation of girls and boys. Participants were sampled from among those who showed a willingness to participate in the FGD when responding to the questionnaire. An example of the discussion questions is: – Would you like to undertake a professional career that involves STEM subjects or not? Please give reasons for your answer. The average duration of the FGDs was 33 minutes.

Data analysis

The data were cleaned to eradicate any wrongly entered data and the missing values analysis were analysed. The analysis of missing values was conducted whereby 48 respondents (4%) with more than 10% missing values were excluded from the dataset, making the study remain with 1,382 respondents. The remaining missing values were completely missing at random (MCAR) with Little's MCAR test ($\chi 2 = 88.56$, df = 82, $p = 0.29$) as Peugh and Enders (2004) argue that data are MCAR when Little's MCAR test is not statistically significant. Subsequently, the expectation-maximization method was used to impute the missing values for it is considered a useful imputation technique with data MCAR (Musil et al., 2002). Skewedness and kurtosis values were below 2 and 4 for each sub-scale respectively, which means that the data met the normality assumption (Finney & DiStefano, 2013).

The data were analysed using descriptive statistics, regression analysis, and content analysis techniques. Particularly, the qualitative and quantitative data were analysed using relevant data analysis software. The FGDs were recorded verbatim by using a voice recorder and thereafter transcribed. The transcripts were entered into the MAXQDA software for analysis using content analysis procedures (Braun & Clarke, 2006). To determine inter-rater coding reliability, the obtained code segments were coded by two independent coders whereby an inter-rater agreement of Krippendoff's value of 0.79 was attained with a coding agreement of 89.4%, which is an ideal level of agreement. The inter-rater disagreements were discussed among the raters and resolved, leading to the agreement to use the dataset with many code segments. Finally, the themes were quantified and participants' quotes were summarised for presentation. Meanwhile, the quantitative were analysed by using descriptive and regression analyses with the help of SPSS version 25.

Results and Discussion

Students' perceptions of participation in science and mathematics subjects

This study investigated the factors influencing secondary school students' participation (or lack thereof) in science and mathematics subjects in Tanzania. The first research question was on how students perceive their participation in science and mathematics subjects in Tanzanian secondary schools. Data for this question were descriptively analysed. The findings indicated that students' attitudes in science and mathematics varied across subjects. Specifically, students had a positive attitude toward their participation in science (M = 4.62, SD = 0.91) and somewhat in Mathematics (M = 3.98, SD = 0.92) as indicated in Table 3. Although Mathematics is considered the gateway to STEM professions, it was the least preferred subject. This suggests that to enable students to pursue STEM careers, efforts should be made to promote students' attitude to participate in Mathematics. Besides, further analysis was conducted to find out whether students' participation in science and mathematics varied by gender and parents' socioeconomic status. The findings indicated that students' attitudes towards participation in Mathematics significantly differed by gender, with the male students having more positive attitudes than their female fellows. Also, participation in Mathematics significantly differed between rural and urban students, with the students studying in urban schools being more interested than their fellows from rural schools (see Table 4). The observed differences in students' attitudes towards participation in some of the STEM subjects could also explain the gender discrepancy in students' performance. Regarding the quality of teacher feedback, students had a positive perception and were willing to use teacher feedback to improve their learning.

Table 4

Student Participation in STEM across Gender and School Location

Construct	Gender			*Location*		
	Female	Male	*t-value*	*Rural*	*Urban*	*t-value*
Mathematics attitude	3.91 (.90)	4.06 (.94)	-3.053*	3.89 (.92)	4.09 (.90)	-4.122*
Science attitude	4.59 (.90)	4.66 (.92)	-1.381	4.64 (.86)	4.60 (.95)	0.813
Mathematics feedback use	5.04 (.82)	5.03 (.87)	3.66	5.05 (.83)	5.01 (.86)	0.928
Science feedback use	5.16 (.81)	5.09 (.92)	1.557	5.20 (.78)	5.04 (.94)	3.524*

Note. Mean (SD) = Standard deviation, * $p < .001$

Further analysis of the data from focus group discussions indicated that several motives make students interested in participating in STEM subjects. Almost half of the students (48%) were interested in specializing in STEM subjects to fulfil their career aspirations. Particularly, these students were aware that being a doctor or an engineer requires one to study STEM subjects. The second reason for students' participation in science and mathematics subjects was related to the increasing demands of STEM experts at the national and global levels. Specifically, students pointed out that national plans for the efforts to become a middle-income economy by 2025 prioritise STEM subjects. Similarly, students acknowledged that the global agenda requires scientists, who are obtained from individuals who pursue STEM subjects. The perceived high employability of STEM graduates was another motive for students' participation in science and mathematics subjects as revealed by the words of one student who said, '*...there are high employment opportunities in science careers, I want to be among the few (School 1)*'. Lastly, the students noted that science and mathematics are essential in addressing societal problems. Specifically, they pointed out that as the country, science and technology experts are highly needed in addressing societal problems such as health, infrastructure, and nutrition-related challenges.

The findings for this question indicated that students positively rated their participation in science and mathematics subjects, with mathematics having the lowest rating. These findings underscore the need to promote students' positive attitude and participation in Mathematics as a gateway to STEM professions. While mathematics is considered the mother of STEM professions, students had low attitudes toward participation in it despite being potential in inculcating science and mathematics values among future experts (Dickerson et al., 2015). Based on the findings, the future of science and mathematics fields highly depends on the promotion of positive attitudes towards science and mathematics subjects. Qualitative findings indicated that students were interested in science and mathematics subjects due to career aspirations and the need to increase employability chances, something which is also reported in previous studies (Rosenzweig et al., 2019). Unlike previous studies, the findings of the current study indicated that students were driven by the problem-solving approach in the sense that science and mathematics careers are likely to address the challenges facing their community. Also, students were informed that science and mathematics education feeds into national priorities and plans. The analysis of the scale's interrelations indicated that students' attitudes to participate in science, and mathematics were moderately related, implying that the promotion of science and mathematics education needs to be holistic, focusing on all related subjects as opposed to subject-specific interventions.

Predictors of students' participation in science and mathematics subjects

The second research question was on the extent to which the variance in students' participation in science and mathematics subjects is predicted by their entry performance, gender, and parents' socioeconomic status. The results of regression analysis indicated that students' participation in mathematics learning was significantly predicted by previous grades in that subject (in Standard 7), father's occupation, school location, and the perceived usefulness of teacher feedback on tests and examinations. Table 5 presents the predictors of students' attitudes toward participation in science and mathematics subjects.

Table 5

Predictors of Students' Participation in Science and Mathematics Subjects

Variable	[a]Mathematics (β)	[b]Science (β)
Mathematics grade	.284**	-
Science grade	-	.090*
Gender	.056*	.054
Parent's education	.034	.060*
Fathers' occupation	-.063*	-.017
Mothers' occupation	-.015	-.035
Location	.051*	-.016
Feedback use	.324**	.466*

Note. **p<.001, *p<.05

[a]Test statistics: adj. $R^2 = .254$, $F(9, 241) = 42.22$, $p = .000$, $f^2 = 0.34$

[b]Test statistics: adj. $R^2 = .270$, $F(9, 228) = 45.84$, $p = .000$, $f^2 = 0.37$

The findings in Table 5 indicate that students' participation in science subjects was significantly predicted by their previous performance in science, parents' education level, and the perceived usefulness of teacher feedback on science tests and examinations. Generally, prior performance in the standardised Standard 7 national examination in a particular subject and the perceived usefulness of teachers' instructional feedback emerged as the strongest predictors of students' participation in science and mathematics. Meanwhile, gender was a significant predictor of students' involvement only in mathematics, implying that the subject is gendered due to the existence of gender stereotypes favouring male students. Concerning Cohen's (2016) interpretation of effect size, the predictors significantly affected students' attitudes toward mathematics (explaining 34% of the variance) and 37% of the variance in science attitude.

Findings indicated that students whose parents had higher education were more interested in mathematics and science than those whose parents had lower education. These findings resonate with previous studies which have established that students' performance in STEM subjects is highly related to the socio-economic status of the parents, especially in developing countries (Eriksson et al., 2021). Particularly, in societies where teaching and learning resources are scarce, parents have a role to play in facilitating their children's education by purchasing those resources and providing cognitive and social support to their children, which is significantly related to academic performance (Kyaruzi et al., 2019). This could also explain the perceived support that students get from their parents, which partly includes the provision of teaching and learning materials. Unlike in previous studies (e.g., Kinyota, 2023), gender, parent's education, and mother's education did not predict students' participation in mathematics learning. Nevertheless, the findings point to the significant impact of previous performance or grade in predicting secondary school students' learning of mathematics and science. Therefore, there is a need to build a strong STEM foundation at the lower education levels. Likewise, teachers' instructional feedback was found to be a strong predictor of students' interest and participation in science and mathematics subjects. This points to the power of feedback in scaffolding students' learning (King et al., 2009; Kyaruzi et al., 2019), promoting interest in the subjects, and making learners highly self-efficacious (Bandura, 1997; Deci & Ryan, 2013).

Barriers to students' participation in science and mathematics subjects

The third research question was on the factors that hinder students' participation in science and mathematics and how they could be addressed. The analysis of data from focus group discussions with students indicated that several factors hindered students' participation in science and mathematics including a shortage of teachers (33%), a shortage of textbooks and inadequacy of lab equipment (33%), and discouragement from peers and adults (34%). Table 6 summarises the hindrances of students' participation in science and mathematics subjects.

Table 6

Barriers to Students' Participation in Science and Mathematics Subjects

Construct	Sample focus group excerpts
Shortage of Science and Mathematics teachers (N = 9, 33%)	…There is a shortage of science and mathematics teachers – the few available teachers are teaching examination classes (School 5).
Shortage of textbooks and lab equipment (N = 9, 33%)	…there is rare lab testing in the laboratory due to a lack of lab equipment, and a scarcity of science textbooks (School 2)... We do not conduct practicals and demonstrations; I have never done practicals since Form 1 (School 3).
Discouragement from peers and adults (N = 10, 34%)	…Sometimes when studying science, we are discouraged by our fellow students (School 6)……We are discouraged by art teachers not to take science and encourage us to study arts subjects (School 3).

The findings in Table 6 imply that students' participation in science and mathematics subjects is affected by a shortage of teachers. Particularly, students reported that in some science and mathematics subjects, they had one teacher who was mainly assigned to teach examination classes. It was noted in one school that most teachers gave excuses for not teaching due to tiredness after teaching several classes without a break as evidenced by the focus group discussion excerpt below:

> The collaboration between teachers and students is not strong. In science, the teacher needs to attend classes regularly and ask many questions. However, in our school, we find that teachers are few and they still have a lot of other responsibilities, which is a challenge (School 3).

Another challenge was the acute shortage of textbooks and lab equipment, which limited students' learning opportunities. While many schools had buildings for science laboratories, they had limited lab equipment and chemicals which confined them to theoretical learning because the laboratory chemicals and equipment available were reserved for examination classes. This was elaborated by one participant during a focus group discussion, who said:

> The main challenge we are experiencing is the shortage of laboratory and equipment. First of all, we have a Physics laboratory, which contains all the equipment for Biology and Chemistry as well, so there is a mixture of equipment which leads to disturbance. Also, we don't have

> enough equipment to study science subjects practically. For instance, when doing the simple pendulum experiment, we use a stopwatch and others use a normal watch, which could mislead us (School 6).

Furthermore, the students were discouraged from taking science and mathematics subjects by fellow students and by other teachers (non-science teachers). Due to the persistent failure in science and mathematics subjects, especially Mathematics and Physics, the students were told that, like others, they would eventually fail in those subjects. The following excerpts from students and teachers attest to this:

> Another challenge is peer pressure. For example, in class, if other students see you studying Science and Mathematics, they discourage you, telling you something like, 'Didn't you see so-and-so last year? They were excelling in science but failed in the end. So, you shouldn't focus on science, it's better to do arts subjects (School 5).

> Some teachers sometimes discourage us from pursuing our interests. For instance, an art teacher who originally wanted to study science might discourage you from studying chemistry, saying it is too difficult. This lack of support makes it hard for us to decide what we want to study (School 1).

Lastly, due to poor pedagogical skills, particularly the skills of handling students who fail in these subjects, teachers resort to the use of poor instructional practices such as punishment. Such ill practices evoke anxiety toward participation in science and mathematics subjects, subsequently lowering students' performance.

The analysis of the findings indicated that science and mathematics education was hampered by a shortage of resources – human resources (subject teachers) and material resources (textbooks and lab equipment). The shortage of teachers is considered a strong barrier because, with the presence of teachers, students are likely to excel in science and mathematics subjects irrespective of other constraints. The findings further revealed that schools suffer a lack of textbooks and lab equipment needed to aid science learning. While textbooks and lab equipment are essential in promoting authentic learning, the findings indicated that they are in a dire shortage in school, hence students are likely to learn superficially. Based on the findings, there is a pressing need to promote meaningful science and mathematics learning through practice-based methods. Likewise, students' science and mathematics learning were barred by social factors such as being discouraged by peers and significant adults. In particular, previous studies show that there exists a societal bias towards the subjects, especially Mathematics and Physics which are perceived as difficult subjects. Such societal bias discourages students from pursuing science and mathematics subjects. Hence, there is an urgent need to promote scientific literacy in the community as the precursor for potential scientists and mathematics experts (Falk et al., 2016). Lastly, the findings showed that students' science and mathematics learning was hindered by teachers' use of ill-pedagogical practices such as punishing the students during the learning sessions. This calls for positive interactive approaches and feedback practices to be used to promote relatedness and student engagement (Kyaruzi et al., 2019; Wood, 2019).

Based on the findings, several theoretical and practical implications can be drawn. First, given that students positively perceive science and mathematics subjects, they are likely to pursue STEM-related careers if there is a conducive learning environment with enough human and material resources. Consistent with self-determination theory, the findings emphasise the role of a conducive learning environment, which depends on parents' socioeconomic status on students' attitudes towards STEM subjects. Also, students' attitudes toward science and mathematics were highly related, calling for a holistic approach to promoting science and mathematics education as opposed to subject-focused interventions. This is again consistent with the self-determination theory, which postulates that students' prior performance predicts students' attitudes and participation in those subjects (Chiu, 2024; Deci & Ryan, 2013). The implication of this is that successful interventions should begin at lower levels such as the primary school level. The findings advocate for earlier interventions for students' interests that vary across education levels (Carr et al., 2023). Additionally, the fact that instructional feedback was a strong predictor of students' participation in science and mathematics subjects is a call for teachers to use effective instructional practices that scaffold students' learning (Kyaruzi, 2019). In contrast, ill-instructional practices such as poor punishment cause students to shy away from participating in science and mathematics subjects. Science and mathematics teachers need to be oriented by using innovative and learner-centred pedagogies that place learners at the centre of the learning process. As Kyaruzi et al. (2019) argue, formative feedback that scaffolds student learning promotes students' participation and performance in those subjects.

Also, the findings indicated that resource-based, relational, and pedagogical-based challenges barred students' participation in science and mathematics subjects. These need to be addressed to promote science and mathematics education. Particularly, there is a pressing need to recruit more science and mathematics teachers and educate the community on the role of scientific knowledge to get rid of the reported stereotypes towards science and mathematics subjects. Lastly, while Marks (2008) found that the mother's occupation was a significant predictor of students' performance in several countries, the current study did not find any evidence for that. This could be attributed to the nature of the sample used as 90% of the mothers had low levels of education. These findings call for further inquiry into the matter by using a systematic sample considering various education levels and occupations of parents. Demographic variables such as students' gender and parents' socio-economic status and education levels interacted with students' attitudes towards and choices of science and mathematics. Specifically, the findings revealed that students whose parents had higher education (graduates and above) had more positive attitudes towards participating in mathematics and science subjects compared to students whose parents had lower education. The findings call for improved levels of society education, with the government initiatives to extend basic education from primary to secondary levels (MoEVT, 2023).

Conclusion

Although students showed a positive attitude towards participation in science and mathematics subjects, their performance in those subjects was not promising, calling for strategic interventions to address the associated barriers. Such interventions need to be timely to realise the national strategic plans for fostering scientific development. Extending the relatedness aspect of the self-determination theory, the findings call for improved science and mathematics teachers' instructional practices that value and place learners at the centre of the learning process. The findings highlight the positive impact of teachers' instructional feedback practices on students' participation in mathematics and science subjects. The findings from this study are significant to other educational systems that struggle to improve students' participation in science and mathematics subjects. Nonetheless, although data for this study were systematically collected and analysed, findings could be substantiated with evidence from studies with longitudinal and experimental designs. Since this study was conducted in public schools, future research could explore students in other school categories, including private schools, which may offer different learning environments. Kibona (2023) highlights that some private schools exhibit no gender gap in students' performance in science and mathematics. Future studies could also examine the impact of parents' socioeconomic status on students' participation and performance in private and public schools to inform strategic interventions in promoting equity in science and mathematics subjects.

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The Effect of the Experimentation Method on Students' Learning Achievement in Geometry: Evidence from Dar es Salaam, Tanzania

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Abstract

The problem of students' poor performance in Basic Mathematics cannot be solved without teachers' use of experimentation methods in teaching and learning Geometry. This present study evidenced that, the teaching and learning of Geometry is effective through experimentation methods. The study aimed to conduct teaching and learning experiments to compare the results of experimentation and non-experimentation methods in Tanzania. Using a quantitative approach grounded in positivist assumptions, quasi-experiments were conducted with experimental and control classes in four Ordinary Level secondary schools. Following a hypothesis, data collected through pretest and post-test were analysed using the paired and independent samples t-tests with the help of Cohen's d. The findings from a sample of 211 students revealed that the non-experimentation methods are not effective in learning Geometry. Besides helping to reach the schools, the probability sampling procedures enabled the arrangement of classes. The study recommends the use of experimentation methods in teaching and learning Geometry. As regards the limitations of the current study, further studies are also recommended.

Keywords: *active learning, transmission teaching, abstract concepts, traditional learning, students' performance*

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Introduction

Students' performance in compulsory Mathematics in secondary education is reported to be low worldwide. According to the Programme for International Students Assessment ([PISA], 2003), "students failed to demonstrate consistently that they had baseline Mathematical skills" (p. 91). Fourteen years later, PISA (2017) reported a low learners' performance in Mathematics worldwide especially in the schools where students had insufficient knowledge of Geometry. PISA (2017) highlighted that "the Mathematical performance can be seen in detail through problem-solving activity related to Geometry" (p. 10626). As PISA (2022) noted, students still face Mathematical challenges, which justifies a consistency in learners' poor performance worldwide. In addition to PISA's report, studies from different countries have reported consistently poor learners' Mathematical performance in secondary education. These include studies such as those in Malaysia (Abdullah & Zakaria, 2013), Cyprus (Panaoura, 2014), Tanzania (Kitta, 2015; Kyaruzi, 2023), Kenya (Ndinda, 2016), Namibia (Kanandjebo & Ngololo, 2017), Ghana (Rizki, Frentika, & Wijaya, 2018; Armal & Kissi, 2019), Iraq (Serin, 2018), Indonesia (Watan & Sugman, 2018), Turkey (Kandil & Bostan, 2019), the USA (Yi, Flores, & Wang, 2020), and Rwanda (Ntivuguruzwa & Mbarute, 2022).

Tanzania faces a critical challenge of poor student performance in Basic Mathematics at the ordinary level of secondary education. Mazana et al. (2020) reported that, on average, 82.5% of candidates failed Mathematics between 2008 and 2016. Similarly, records indicate that 80.9% of candidates failed the subject from 2014 to 2020 (MoEST, 2016; NECTA series, 2019–2020). Notably, the failure rate in Geometry is higher than in other Mathematics topics (NECTA series, 2014–2015, 2017–2019). This trend is concerning, as Geometry constitutes more than 60% of all Basic Mathematics topics (MoEST, 2017; MoEST, 2023). Despite the shift from a content-based to a competence-based curriculum in 2005 (Kitta, 2015; MoEST, 2017), many teachers continue to rely on the lecture method due to several challenges.

First, the syllabus remains overloaded, limiting the feasibility of activity-based learning (Paulo & Tilya, 2014). Second, large class sizes pose a significant challenge. While the government recommends a maximum of 40 students per class, many secondary school classrooms exceed this limit, accommodating more than 70 students (Mashala, 2019; Ndibalema, 2019; Godda, 2018; Siperto, 2018; HRW, 2017). For instance, a study by Siperto (2018) found that the average class size in O-level secondary schools in Buchosa District Council, Mwanza Region, was as high as 100 students. Large class sizes hinder effective classroom engagement and instructional strategies (Godda, 2018), making it hard for teachers to provide individualised support (HRW, 2017). Another major constraint is the severe shortage of Mathematics teachers (Human Rights Watch [HRW], 2017). For example, at one secondary school in Mwanza with 569 students enrolled in January 2016, only one out of 29 full-time teachers was a Mathematics teacher (HRW, 2017). This shortage often results in merged classes and increased teaching loads, limiting teachers' preparation time. Consequently, students' performance in Geometry remains consistently poorer than in other Mathema topics, as shown in Table 1.

According to PISA (2017), "Geometry is a fundamental branch of science in Mathematics and an essential component for developing mathematical thinking skills. Mathematical performance can be assessed in detail through problem-solving activities related to Geometry" (p. 10626). These statements suggest that Geometry serves as a foundation for understanding other areas of Mathematics, a notion that has also been recognised in Tanzania. In its Curriculum and Syllabus for Pre-primary Education, the Ministry of Education, Science and Technology [MoEST] (2023) states that "Early Numeracy Skills, such as identifying shapes, comparing and measuring objects, and analysing and arranging objects in a uniform order, help a child develop a broader understanding for making informed decisions" (p. 5). MoEST (2023) further states that these skills enhance a child's confidence and courage, which are crucial for academic progression and daily life. Similarly, in the USA, Yi et al. (2020) highlight that "familiarity with shapes, structures, locations, transformations, and proofs provides a foundation for understanding not only other areas of Mathematics but also subjects such as art, science, engineering, and social studies" (p. 1).

Despite the significance of Geometry, students in Tanzania perform worse in this area compared to other Mathematics topics, as reflected in Table 1. The data indicate that the lowest pass rate (0.7% in 2015) was recorded in Pythagoras' Theorem and Trigonometry, both of which are Geometry topics, whereas the highest pass rate (80.7% in 2014) was in Accounts, a non-geometry topic. Furthermore, other Geometry topics, such as perimeter, areas, and similarity, are among those with the lowest pass rates. Notably, all Geometry-related topics recorded a pass rate of 30% or lower, with most below 20%, except for Circles, Three-Dimensional Figures, and the Earth as a Sphere, which had a pass rate of 21.3% in 2019. Each year, NECTA conducts a topic-based analysis of students' performance in national examinations. Table 1 presents data for the years 2014–2020, during which the same set of topics was analysed. The table summarizes the percentage of candidates who passed each topic annually, offering insight into the persistent underperformance in Geometry.

Table 1

Analysis of Candidates' Performance Topic–wise in Basic Mathematics CSEE 2014-2015, 2017-2020

S/N	Topic/Subtopics	Percentage of Candidates who Passed						
		2014	2015	2017	2018	2019	2020	Average
1	Accounts	80.7	42.0	73.9	77.7	25.1	39.6	56.5
2	Statistics	47.9	29.9	56.8	50.1	53.4	50.3	48.1
3	**Linear Programming	35.4	53.6	07.0	34.7	25.6	16.5	28.8
4	Numbers, Fractions and Decimals	18.7	20.6	23.2	33.3	23.9	13.3	22.1
5	Rates and Variations	49.8	13.6	22.8	23.1	33.9	31.5	27.1

6	**Matrices and Transformations	29.6	16.5	25.6	20.3	22.7	21.6	22.7
7	Ratios, Profit and Loss	24.3	02.4	05.1	18.1	21.2	39.6	18.5
8	Sets and Algebra	35.2	07.8	19.0	17.3	18.5	8.2	17.7
9	*Pythagoras Theorem and Trigonometry	08.0	00.7	03.4	17.0	18.1	25.6	12.1
10	Sequences and Series	15.7	04.7	02.7	12.3	05.7	39.9	13.5
11	**Quadratic Equations	10.1	07.3	07.8	10.9	16.6	6.3	19.8
12	Exponents and Logarithms	14.5	12.3	15.3	10.2	12.8	14.4	13.3
13	**Functions and Probability	30.6	22.1	15.9	08.3	12.3	16.5	17.6
14	*Circles, Three Dimension Figures and Earth as a Sphere	09.3	12.9	08.3	07.5	21.3	8.6	11.3
15	*Vectors and Coordinate Geometry	14.8	06.1	14.6	05.3	15.9	17.1	12.3
16	*Perimeters, Areas, Congruence and Similarity	03.0	02.1	02.5	03.4	12.1	17.3	6.7

Source: NECTA series (2014-2015, 2017-2020)

* Geometry topics
**Topics which require prior knowledge of Geometry

Studies conducted on Geometry in other countries have emphasised the use of experimentation methods in teaching and learning Geometry. For example, in Malaysia, Abdullah and Zakaria (2013) noted that "Geometry learning should emphasise hands-on and mind-on approaches" (p. 252). This finding is similar to what was observed in Indonesia by Watan and Sugman (2018) who maintained that, "in Geometry, instructions are designed to explore problems by rotating, folding, measuring and drawing to obtain the implicit nature of concepts with teacher guidance" (p. 7). These findings emphasise experiments, which is learning by doing. Experiments such as paper folding can lead to a discovery of principles about angles and lines as confirmed by Ndinda (2016) in Kenya, and to a rise in learners' performance in Geometry and other Mathematics as reported by Kurniati (2017) in Indonesia. Again, in Namibia, Kanandjebo and Ngololo (2017) suggested the use of ICT-driven pedagogy when teaching Geometry for students to grasp the concept of Geometry instead of memorising formulae. However, experimentation methods are not effectively practised in Tanzania (Paulo & Tilya, 2014; Kisakali & Kuznestov, 2015; HRW, 2017; Godda, 2018; Siperto, 2018; Mashala, 2019).

Furthermore, many of the studies conducted on Ordinary level secondary Mathematics in Tanzania are not focused on Geometry. For instance, Mazana et al. (2020) assessed students' performance in Mathematics while Kisakali and Kuznetsov (2015), Mabula (2015) and Michael (2015) observed factors leading to poor performance in Mathematics. Kitta (2015) contributed to specific projects whose aims involved improving teacher classroom practices. However, the studies conducted by Justini (2015) and Sichizya (1985) focused on Geometry. Justini (2015) was directed to primary schools and did a teaching experiment in Geometry with the control group learning through the lecture method while the experimental group was taught using the demonstration method. In this case, pupils were not allowed to participate in constructing Geometrical figures and doing the activities of locating and measuring angles and lengths as advocated by Panaoura (2014). This present study intended to achieve the practical work mentioned by Panaoura (2014) since it suggests the use of experimentation methods.

Although the study by Sichizya (1985) is somewhat old, it also failed to focus on teaching and learning methods. The study aimed to determine the extent to which factors such as the availability of Geometry equipment, school management, teacher experience, and both pupil and teacher attitudes toward Geometry influenced pupils' performance. It primarily compared the achievement of pupils in Geometry across schools with at least half of the required equipment (10 items listed in a checklist) and those with less than half of the equipment, without considering the teaching methods employed. Sichizya (1985) found that "the mean score for pupils in schools with at least half of the equipment was 6.59, while in schools with less than half, it was 3.56 out of 20 scores. When subjected to the t-test, the difference was statistically significant at the 0.1 level" (p. 64). Instead of focusing on experimental methods, Sichizya (1985) concentrated on factors that could affect the teaching and learning of Geometry. Consequently, the issue of teaching Geometry through non-experimental methods in Tanzania remains inadequately addressed.

As noted earlier by researchers from other countries, Geometry knowledge is crucial for representing and solving problems in other Basic Mathematics topics, and the teaching and learning of Geometry is most effective through experimental methods. This study suggests that there may be a missing link between the measures currently being taken and the root cause of learners' poor performance in Basic Mathematics in Tanzania. As Table 2 indicates, there is a persistent and significant failure rate in Basic Mathematics (averaging 80.9%), despite various interventions. Additionally, Table 1 further reveals that failure rates are disproportionately high in Geometry topics (averaging 91.36%) compared to other Basic Mathematics topics (averaging 75.22%). Although Geometry constitutes more than 60% of all Basic Mathematics topics in Tanzania, as outlined in the syllabus, little has been done to address the issue of excessive failure in this area. Studies conducted in

Tanzania have not focused on experimental methods, which have been shown in other countries to be more effective in teaching and learning. If the issue of students' failure in Geometry is not addressed, it will continue to adversely affect their overall performance in Basic Mathematics.

Table 2

Comparison between Pass and Fail Rates in Basic Mathematics

CSEE 2014 to 2020

Year	2014	2015	2016	2017	2018	2019	2020	Average
Pass	19.6	16.8	18.1	19.2	20.0	20.0	20.0	19.1
Fail	80.4	83.2	81.9	80.8	80.0	80.0	80.0	80.9

Source: MoEST (2016), NECTA (2019) & NECTA (2020)

Table 2 indicates that, on average, 80.9% of the candidates failed Basic Mathematics in the Certificate of Secondary Education Examinations (CSEE) each year despite measures being continually taken by the Tanzania government. The measures that are being taken by the government include the enhancement in teaching and learning environments, the change in classroom instruction methods, and teacher training programmes (Mazana et al., 2020)

To address the research problem, this study aimed to achieve the following specific objective:

To compare the performances of students exposed to experimental methods with those exposed to non-experimental methods in learning Geometry among ordinary-level secondary schools in Tanzania.

The corresponding hypothesis for this objective is as follows:

There is no significant difference in performance between students exposed to experimental methods and those exposed to non-experimental methods in learning Geometry.

Literature Review and Theoretical Framework

Literature review

Importance of mathematics

Mathematics plays a crucial role in everyday activities. For instance, a tailor requires mathematical skills to perform the necessary calculations when designing garments, while a mason relies on mathematics to lay bricks correctly. Similarly, carpenters, mechanics, plumbers, plate layers, and other craftsmen need a certain level of mathematical knowledge to succeed in their careers. As a result, various researchers emphasise that mathematical competencies are widely applied across many areas of human life (Mensah, Okyere, & Kuranchie, 2013; Tanveer, Rizwan, Ali, Arif, Saleem & Rizvi, 2013; Kisakali & Kuznetsov, 2015). These competencies are particularly important in scientific and technological development, as mathematical skills are essential for understanding other disciplines, including engineering, economics, business, natural sciences, social sciences, and even the arts (Tanveer et al., 2013). In this context, MoEVT (2014) reported that nearly every field of science in Tanzania relies on mathematical concepts, theories, and models. Mathematics is vital for understanding modern technology, and as noted by Kisakali and Kuznetsov (2015), it is taught at all levels of education in Tanzania, from pre-primary through Ordinary secondary education. Mathematics forms the foundation for both social and natural sciences through the development of principles, and it is widely applied in business, economics, engineering, and agriculture. Furthermore, it aids in logical reasoning and the organisation of proofs. However, despite its importance, there continues to be a significant failure rate in Basic Mathematics (Mazana, Montero & Casmir, 2020; MoEST, 2016; NECTA, 2019; NECTA, 2020).

Basic mathematics topics in Tanzania

According to MoEST (2017), Basic Mathematics in Tanzanian Ordinary-level secondary schools covers 38 topics, including numbers, fractions, decimals and percentages, units, approximations, and geometry. Other topics include algebra, ratios, profit and loss, coordinate geometry, perimeters and areas, exponents and radicals, quadratic equations, logarithms, congruence, similarity, geometrical transformations, the Pythagorean theorem, trigonometry, sets, statistics, relations, functions, rates and variations, sequences and series, circles, spheres, accounts, three-dimensional figures, probability, vectors, matrices and transformations, and linear programming. Of these, 14 topics are purely related to Geometry: perimeters and areas, coordinate geometry, congruence, similarity, geometrical transformations, the Pythagorean theorem, trigonometry, geometry, circles, spheres, and three-dimensional figures. These constitute 36.8% of all Basic Mathematics topics, more than one-third of the syllabus. While other topics such as relations, functions, vectors, matrices and transformations, linear programming, and quadratic equations are not exclusively Geometry, students cannot master them without prior knowledge of Geometry. In general, based on the Basic Mathematics syllabus (MoEST, 2017), Geometry covers more than 60% of all topics. This is also reflected in the new Basic Mathematics syllabus (MoEST, 2023), which focuses on competencies rather than specific topics. For instance, two of the three main competencies of the syllabus emphasise Geometry (MoEST, 2023:3), representing more than 60% of the content.

The place of learning methods in learners' performance

The importance of learning methods has long been receiving the consideration of many scholars worldwide. For instance, Tyler (1949), a classical American writer and Professor in the field of curriculum, highlighted that "although the particular learning experiences appropriate for attaining educational objectives will vary with the kind of objectives aimed at, teachers should have learnt certain principles that apply to the selection of learning experiences, whatever the objectives may be" (p. 65). Sixty-seven years later, Ifeoma (2016) in Nigeria argued similarly that "whatever learning outcomes students attain depend on what goes on in the classroom between teachers and students" (p. 82). The Nigerian national policy on education emphasises the importance of teachers, stating that "no education system can rise above the quality of its teachers" (Ifeoma, 2016, p. 82). Similarly, in Rwanda, Uwineza, Rubagiza, Hakizimana, and Uwamahoro (2018) argue that "students' performance in Mathematics depends on teachers' classroom gender-related practices" (p. 44).

The voice of educational researchers across the world is unanimous on the importance of learning methods. For instance, in Cyprus, Papanastasiou (2008) noted that teaching methodology has a direct effect on achievements in Mathematics and also on students' attitudes towards Mathematics, class climates and students' Mathematics self-perception. Papanastasiou (2008) discovered that the factor that accounts for the greatest differences related to Mathematics achievement between the more effective and less effective schools is transmission teaching, while the second factor is active learning. The other factors were successively mentioned as self-perception, student attitudes toward Mathematics, family incentives, and class climate. Therefore, based on such references like these, the prevailing study was conducted on learning methods. But it focused on comparing only experimentation and non-experimentation methods that are viewed by scholars in other countries that, participatory learning methods cause learners' high achievement in Geometry which leads to excellence in students' Mathematics performance (Abdullah & Zakaria, 2013; Panaoura, 2014; Seago et al., 2014; Tieng & Eu, 2014; Boakes, 2015; Ma et al., 2015; Ndinda, 2016; Kurniati, 2017 Watan & Sugman, 2018; Serin, 2018; Kandil & Bostan, 2019; Kumar et al., 2019; Kuzle & Gracin, 2019; Yi, Flores & Wang 2020). Furthermore, it has been provided that computer design systems promote experimental learning as students become involved in the discovery and construction of their knowledge (Das, 2019; Kumar & Kumaresan, 2020).

Theoretical framework

This study selected Van Hiele's theory of Geometric thinking which emphasises experimentation methods, and hence highlighting procedures recommended in other countries' literature about the teaching and learning of Geometry. Scholars such as Yi et al. (2020), Watan and Sugiman (2018), Ma, Lee, Lin and Wu (2015), and Abdullah and Zakaria (2013) have described Van Hiele's theory in five levels of learning: visual, descriptive, theoretical, formal logic, and rigour (the nature of logical laws).

At the first level, students learn Geometry through visualisation. They are provided with figures which are judged by their appearances. The current study aimed to improve this level by involving students in the construction of shapes as it was said by Panaoura (2013), a point that is not emphasised in Van Hiele's theory. At the second level figures are judged by their properties. A student may realise that the opposite sides of a rectangle are congruent. Students related figures and their properties in the third level. For instance, a student could understand why every square is a rectangle. At the fourth level, students could build deductive Geometric proofs because they understood the definitions and properties of figures. For example, students could prove why the diagonals of a rectangle are congruent. Lastly, at level five, students understand the way how mathematical systems are established. They can use all types of proofs and they can prove theorems. According to Tieng and Eu (2014:4), "to function successfully at a particular level, a learner must have acquired the strategies of the preceding level." The role of the teacher at every level is to provide students with necessary activities and guide the interactions using experimentation methods such as cooperative learning, discovery learning, Socratic Method, project-based learning and inquiry method.

Research Methodology

This study was guided by the assumptions in the positivist paradigm. The article presents findings from quasi-experiments that were conducted using quantitative methods. While the population of the study was all Ordinary level secondary schools in Tanzania, the target population consisted of only 14 schools (in the Dar es Salaam region) which appeared among the top ten schools and last ten schools in the country from the years 2016 to 2020.

Study area

In selecting a study area, Creswell (2018) advises researchers to consider the heterogeneity of the study population and to choose locations that reflect a range of variations in key characteristics. Dar es Salaam Region was purposively selected as it consistently contributed a significant number of schools to both the lowest – and highest-performing categories. Notably, in 2016, six of the ten lowest-performing schools were from Dar es Salaam (NECTA series, 2016–2020). Therefore, the study was conducted in the Dar es Salaam Region.

Sampling procedures

According to Alvi (2016), if the purpose of research is to draw conclusions or make predictions affecting the population as a whole, then probability sampling is appropriate. Probability sampling is a sampling procedure which uses statistical methods to select elements from a population. It is unbiased as it always facilitates valid conclusions about the population from which the sample was selected (Alvi, 2016). Thus, probability sampling was used to assign schools and participants to the control and experimental groups. In the first stage, stratified random sampling (which is a kind of probability sampling) was used in dividing the schools into two homogeneous subgroups. This is because the population had 14 Ordinary level secondary schools which were heterogeneous as regards performance; seven of them were among the ten best-performing schools in the years 2016 to 2020 while the rest belonged to the worst ten performing schools in that interval. According to Kombo and Tromp (2006), stratified random sampling is a method of selecting a sample that considers strata or the heterogeneous nature of a population by dividing it into homogeneous subgroups. A simple random sample is then taken in each subgroup in a way that proportionally represents the population.

Probability sampling was also used to get a sample of four schools (two schools from each subgroup); an experimental school and a control school were randomly selected from each category. The sample involved two experimental schools and two control schools. In each school, the Form Two class was purposively chosen, since the topic of similarity is in Form Two (MoEST, 2017). This is because Similarity was the leading Topic being poorly performed by candidates (NECTA series, 2014-2015, 2017-2020). One Form Two stream in each of the sampled schools was selected at random and its Mathematics teacher was purposively involved in the teaching and learning experiment. While the teachers who taught the experimental classes received a seminar before they started to teach, the ones who taught the control classes got the seminar at the end of the teaching and learning experiment for ethical considerations. This design collected quantitative data from 211 students (all the students in a stream were included). Thus, adding the four teachers, the sample comprised 215 participants. However, before the teaching and learning experiment could start, it was necessary to know whether or not the control and experimental schools in a subgroup were different or similar in terms of Geometry background knowledge. Therefore, a pre-test was applied which revealed that every pair of schools in each subgroup did not have a statistically significant difference in performance. The details are indicated in the findings and discussion section.

Training duration

The Basic Mathematics teachers who were involved in teaching both the control and experimental groups were oriented to exemplary curriculum materials in a three-day seminar at school H. This seminar was conducted by the researcher during which the mathematics teachers had an opportunity to contribute ideas for improving the exemplary materials. However, for ethical considerations, the teachers in the control schools received their training after data collection just to improve their teaching practices. During the training, teachers' activities in the experimental group included the preparation of figures/shapes, measuring angles and sides, constructing and drawing. In either phase, the timetable was the same. Day 1 was used in constructing diverse figures and discussing their properties and relationships, while Day 2 and Day 3 were devoted to deriving and proving Similarity theorems. Participants had enough time to discuss the applications of Similarity theorems in solving Mathematical and daily life problems. Regarding the teachers who attended the seminar, each possessed a diploma in Education and had teaching experience of more than 10 years in Mathematics.

Exemplary curriculum materials

This constituted activity-based lessons on the topic of similarity. The materials were designed following directives from the current Tanzanian Basic Mathematics syllabus for Ordinary secondary schools (MoEVT, 2017). Textbooks, supplementary books, and past papers were then selected according to the syllabus. However, the exemplary curriculum materials were prepared in such a way that students had the opportunity to do the activities by themselves under teacher guidance. The materials were prepared by the researcher in collaboration with experienced teachers who were acquainted with the teaching of Basic Mathematics in the context of a competence-based curriculum. The exemplary curriculum materials and the test with its marking scheme have been submitted separately from the manuscript.

Validity and reliability of research instruments

The probability sampling minimised threats of internal validities like the maturation, history and testing effects. Furthermore, the validation of instruments used in this study involved scrutinisation of the instruments by peer examiners. On the other hand, the instruments needed to be reliable by being qualified to give similar data when administered repeatedly (Taherdoost, 2016). Each of the instruments was applied to different groups during the teaching and learning experiments to measure the extent to which the groups consistently provided the same results.

Classroom intervention

The oriented teachers then used the exemplary curriculum materials for teaching the experimental groups. The control groups learnt Similarity through conventional methods as their teachers were not included in the seminar at the beginning. The teaching and learning experiment (in both the control and experimental groups) lasted for two weeks, which is the duration indicated in the syllabus for the coverage of the Similarity topic (MoEST, 2017). As the positivism paradigm insists on the privacy of participants to minimise bias (Park et al., 2019), the researcher was not involved in the teaching experiment.

Control of extraneous variables

The confounding or external variables were controlled in several ways which include the probability sampling of schools and participants, and using schools that were distant apart such that each school had only one class, experimental or control but not both. Other ways included the use of the same test and the hiding of hypotheses from participants.

Data analysis procedure

Paired samples t-test statistic was used to analyse the data gathered from the pretest and post-test. This is because the paired samples t-test is used to test if the means of two paired measurements, such as pretest/post-test scores, are significantly different (Warner, 2021). Comparison of means would lead to rejection or acceptance of the null hypotheses (Chittaranjan, 2019) and then enable explanations on whether or not two attributes (learners' scores in this case) are related.

Ethical considerations

This study received approval and permit from the University of Dar es Salaam, the District and Regional Authorities, and the heads of schools.

Findings and Discussion

This section presents the study's results, which are provided as answers to the hypothesis. With the help of SPSS statistical computations such as the Paired Samples t-test statistic, decisions were made concerning the rejection or acceptance of the null or alternative hypothesis.

Comparing the performance of students exposed to experimentation methods and students exposed to non-experimentation methods in learning geometry

The hypothesis of the study was, "Is there a significant difference in performance between students exposed to experimentation methods and students exposed to non-experimentation methods in learning Geometry?" The results are presented as follows:

Results of the pretest

The descriptive statistics of the pretest are shown in Table 3.

Table 3

Pretest Descriptive Statistics

	N	Minimum	Maximum	Mean	Std Deviation
Pretest school 1	51	12	56	46.37	11.278
Pretest school 2	41	17	58	45.29	6.882
Pretest school 3	62	0	16	4.83	4.910
Pretest school 4	57	1	7	4.34	3.487

Source: Field data 2022

The means in the high-performing schools (classes or groups) were 46.0 and 45.0. To discover whether or not the means were significantly different, the results were tested using the paired samples t-test statistic. The significant value was 0.1, which is above the 0.05 significance level. This indicates that the two means are not significantly different (Alnasraween, 2021; Chittaranjan, 2019). Thus, the difference in performance between the two high-performing classes was not significant statistically. In other words, the classes are equal in performance. Again, the means of the low-performing classes (schools) were 4.3 and 4.8. The paired samples t-test indicated a significant value of 0.48 which is greater than the 0.05 significant value. Therefore, the low-performing schools were also equal in performance.

Now, having observed in every pair that the schools were equal, one school in each pair was determined as an Experimental Group and the other one as a Control Group by use of random sampling techniques. That is, the two high-performing schools had now become a pair in which one was experimental group1 while the other was control group1; a change that applies similarly to the two low-performing schools for experimental group2 and control group2. The formation of groups gave room to the beginning of the teaching and learning experiment on the Topic of

Similarity, which lasted for two weeks according to the syllabus (MoEST, 2017). Thus 14 days after the pretest, the same test (now called posttest) was administered to experimental and control groups.

Results of the post-test

The descriptive statistics showing the means and standard deviations are displayed in Table 3.

Table 4

Post-test Descriptive Statistics

	N	Minimum	Maximum	Mean	Std Deviation
Post-test Experimental Group 1	51	76	98	85.92	6.099
Post-test Control Group 1	41	50	87	66.61	9.268
Post-test Experimental Group 2	62	7	85	46.82	19.208
Post-test Control Group 2	57	0	32	12.52	9.300

Source: Field data 2022

In either pair, the mean of the experimental group is higher than that of the control group. When the marks were subjected to the SPSS software, the results were as indicated in the paired samples t-test Table 5.

Table 5

Paired Samples T-Test Regarding Post-Test Results of Both Experimental Group 1 and Control Group 1

<table>
<tr><td rowspan="4">Pair 1:
Post-test Experimental Group 1
Post-test Control Group 1</td><td colspan="5">Paired Differences</td><td rowspan="3">t</td><td rowspan="3">df</td><td rowspan="3">Significant Value (p-value)</td></tr>
<tr><td>Mean</td><td>Std Deviation</td><td>Std Error Mean</td><td colspan="2">95% Confidence Interval of the Difference</td></tr>
<tr><td rowspan="2">19.49</td><td rowspan="2">4.62</td><td rowspan="2">0.72</td><td>Lower</td><td>Upper</td></tr>
<tr><td>18.03</td><td>20.94</td><td>27.03</td><td>40</td><td>0.000</td></tr>
</table>

Source: Field data 2022

Regarding the experimental group 1 and control group 1, the means in the pretest results were 46 and 45 respectively, instead of 86 and 67 as it was in the post-test. This shows an improved performance in both groups, though the experimental class has gained more. Concerning the experimental and control groups, the size of the difference in their means is shown by the t-value of 27.03 as large enough to make the significant value 0.000 below 0.05. This indicates that the means are significantly different. Furthermore, Cohen's d which is calculated as (mean of experimental group-mean of a control group)/ (SD of the control group) = (86-

67)/9=19/9=2.1 indicates that the means differ by two standard deviations; implying a large effect (Verdugo, Garciab, & Tellez, 2015). Therefore, the difference in performance between the experimental group and the control group is significant statistically.

Again, the means of the experimental group 2 and control group 2 are 46.8 and 12.5 respectively. The pretest means were 4.3 and 4.8 respectively. Regarding the means, both the experimental and control groups have gained in performance, but there is a big difference between them which can be interpreted with the help of Table 5.

Table 5

Paired Samples t-Test Regarding Post-test Results of both Experimental Group 1 and Control Group 1

Pair 1: Posttest Experimental Group2-Posttest Control Group2	Paired Differences					t	df	Significant Value (p-value)
	Mean	Std Deviation	Std Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
	34.28	8.82	1.17	31.94	36.62	29.36	56	0.000

Source: Field data 2022

Table 5 refers to the significant value as 0,000 which is less than the 0.05 significance level. This shows a significant difference in the means. In addition, Cohen's d was calculated with reference to Table 3 as 3.6. This indicates a large effect (Bhandari, 2023). Therefore, the difference between the means is significant statistically. Therefore, the null hypothesis that, "there is no significant difference in performance between students exposed to experimentation methods and students exposed to non-experimentation methods in learning Geometry" is rejected; and the corresponding alternative hypothesis that, "there is a significant difference in performance between students exposed to experimentation methods and students exposed to non-experimentation methods in learning Geometry" is accepted.

There is a gain in performance by both pairs of the groups; the high-performing schools as well as the low-performing ones. Therefore, activity-based learning improves learning achievement in Geometry. There is also theoretical implication of the findings. Involving students before and during periods in doing experiments such as paper folding, constructing figures using materials in the local environment, and drawing and locating shapes, lines and angles on papers or with the help of computer algebra systems such as Mathematica and Maple improves learning as the underpinning theory suggests.

These findings also harmonise perfectly with several studies which were conducted earlier in other countries. For instance, Panaoura (2014:498) discovered that "the understanding of Geometry requires students to construct the appropriate figures to translate the verbal information and solve a Geometrical task." The same observation but in other words was later affirmed by Ndinda (2016) that experiments in paper folding can lead to the discovery of principles about angles and lines that facilitate understanding. These results also concur with the finding by Serin (2018) who contends that the teaching of Geometry is most effective through experimentation methods. Thus, in teaching Geometry topics, which consist of abstract concepts, there is a need for activities that will allow students to learn theoretical information by trying and proving using concrete materials in which learners are actively involved.

Conclusions

The findings of this study established that experimentation methods are the most effective in learning Geometry. The findings have provided clear evidence through repeated statistical tests in several teaching and learning experiments. It was confirmed that by using the traditional approaches (the non-experimentation methods), students' learning of Geometry in secondary schools will not be raised to the desired level. In light of this article, therefore, the study concludes that Geometry topics should receive special activity-oriented considerations involving experimentation methods should be used to teach and learn them. This is because it has been evidenced that Geometry comprises concepts which include more vocabularies than in the other areas of Basic Mathematics topics.

Recommendations

The recommendations are made in light of the study's findings, with a focus on policy considerations, teaching and learning practices, and avenues for further research.

The findings of this study highlight the necessity of using experimentation methods in teaching and learning Geometry to achieve desired outcomes in Basic Mathematics. It is recommended that schools be equipped with adequate classrooms, qualified teachers, and comprehensive teacher training to foster an environment conducive to implementing experimentation methods. The Basic Mathematics syllabus should also clearly differentiate between Geometry topics and other Basic Mathematics topics, as Geometry concepts are often too abstract for learners to grasp without active learning through experimentation methods. Additionally, the study recommends that Geometry topics be taught exclusively through experimentation methods. Special attention should be given to Geometry instruction, even in situations where teachers encounter challenges in adopting participatory methods. This is because non-experimentation methods are ineffective in teaching Geometry. It is also recommended that students be given opportunities to engage with concrete Geometrical materials during lessons and participate in constructing and preparing Geometrical figures before the lessons.

Given that this study compared experimentation and non-experimentation methods by analysing students' test scores in a limited sample of public and private Ordinary-level secondary schools in Tanzania, its scope was confined to one region and four schools. A more comprehensive study is recommended, involving a larger number of schools across the country for comparative analysis. Moreover, as this study employed only quantitative methods, future research should consider using mixed methods to capture a broader range of data and offer a deeper understanding of the issue, which quantitative methods alone cannot fully address.

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Investigating Secondary School Mathematics Teachers' Proficiency with the Use of Jigsaw Collaborative Method in Tanzania

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Abstract

The study was conducted in the Mtwara region of Tanzania to investigate Mathematics teachers› proficiency in using the jigsaw teaching strategy. An exploratory research approach was employed, focusing on six underperforming schools where 10 specialised mathematics teachers were interviewed. Data analysis was conducted using thematic analysis. The findings indicate that many teachers had a limited understanding of the jigsaw method, hindering their effective implementation. Initiatives such as pre-service training, in-service support, and personal efforts were identified as key factors in improving teachers' proficiency with the jigsaw strategy. The study recommends ongoing in-service training and mentorship to enhance teachers› skills in utilising collaborative teaching strategies like the jigsaw method.

Keywords: *jigsaw, teaching strategies, mathematics learning, cooperative learning strategies*

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Introduction

Tanzania, like many other countries in the world, is striving to achieve the 4th sustainable development goal of quality education. This can be accomplished by enhancing mathematical proficiency at various educational stages in Tanzania, which plays a crucial role in realising the country's industrialisation agenda and overall economic development. Unfortunately, Tanzania has long struggled with widespread underachievement in mathematics among secondary school students. This chronic issue is evident through low pass rates in national examinations compared to other subjects, as shown in the data collected from the report of the National Examination Council of Tanzania (NECTA) for five consecutive years.

This data is summarised in Table 1.

Table 1

CSEE Percentage of Pass and Fail Rates in Basic Mathematics (2018 – 2023)

Year	2018	2019	2020	2021	2022	2023	Average
Pass	20.0	20.0	20.0	19.54	20.08	25.42	20.84
Fail	80.0	80.0	80.0	80.46	79.92	74.58	79.16

Source: National Examination Council of Tanzania (NECTA) (2018; 2022; 2023)

Based on the data in Table 1, it is clear that the average percentage of students failing the mathematics national examination from 2018 to 2023 is remarkably high, at 79.16%. This poor performance hinders many students from pursuing careers in science, as proficiency in mathematics is often a requirement for entry into science-related programs at higher education institutions (Mazana et al., 2020). This raises significant concerns about the quality of mathematics education in Tanzania, posing a threat to both future generations and the nation's efforts towards industrialisation and achieving sustainable development goals.

The poor performance in mathematics across all educational levels is attributed to various factors. Mkenda (2022), Kyaruzi (2023), and Francis (2024) pointed to ineffective teaching strategies and students' anxiety, phobia, or negative attitudes toward the subject as key contributors. Moreover, Kinyota (2020) cites the absence of competent teachers and inadequate teaching and learning resources, such as books, as factors leading to high failure rates. Additionally, Kayombo et al. (2022) highlight insufficient teaching aids and a limited number of mathematics teachers in most schools as further factors impacting performance. In contrast, Mazana et al. (2019) suggest that higher failure rates are linked to low levels of teacher motivation, negative teacher attitudes toward students and mathematics, poor instructional strategies, and teachers' weak content knowledge. In this regard, it is worth noting that teachers' competency including understanding relevant teaching strategies have significant contributions towards improved academic performance.

The government recognises the critical importance of providing strong support for mathematics teachers to enhance mathematics teaching and learning. The Ministry of Education, Science, and Technology, in collaboration with other donors, has initiated various programs to enhance the capacity of science teachers to improve learning outcomes. Two key programs include the Science Education in Secondary Schools (SESS) project and the Science Teacher Improvement Project (STIP). The SESS project was implemented in 29 government secondary schools at the Ordinary level in the Coast, Dodoma, and Iringa regions from 1995 to 2003.

The STIP focused on schools under the Christian Social Services Council (CSSC). Additional strategies include the training of more mathematics teachers and the integration of ICT into teacher education and secondary school curricula, since the early 2010s (Kafyulilo et al., 2015).

Despite these efforts, poor performance in mathematics persists. Available studies in Tanzania have generally investigated the effectiveness of a learner-centred approach in teaching mathematics (Mkimbili, 2018; Mbedule, 2020; Kasuga et al., 2022; Mkenda, 2022; Michael, 2015), factors for poor performance from teachers' perspectives (Mazana et al., 2020), barriers to the use of problem-based learning (Kikomelo, 2024), and mathematics teachers' choice of teaching strategies (Mazana et al., 2023). However, none of these studies specifically focused on investigating mathematics teachers'' understanding of the jigsaw strategy in teaching mathematics. The current study is designed to fill this knowledge gap.

Research questions

The study sought to answer the following specific research questions:

i. How do secondary school mathematics teachers conceptualise the jigsaw teaching strategy?

ii. How do secondary school mathematics teachers acquire knowledge about the jigsaw strategy?

Literature Review

Meaningful mathematics learning

Teaching and learning mathematics have been very challenging at almost all education levels due to the diverse learning needs of students. The inability of students to connect the study of mathematics with solving real-life problems creates anxiety among them (Mazana et al., 2019). This has led to persistent failures in mathematics at various education levels in Tanzania and many other countries worldwide. To ensure effective learning, teachers are constantly striving to implement appropriate strategies tailored to the needs and learning styles of young learners. The available literature indicates that meaningful learning of mathematics requires teaching strategies that provide opportunities for hands-on, collaborative, gamified learning, visual representations, and technology integration (Freeman et al., 2014; Rachmah, 2017). By incorporating these innovative strategies into teaching, educators can create dynamic and enriching mathematics learning experiences that foster curiosity, promote deep understanding, and equip students with essential mathematical skills for success.

In Tanzania, the quality of mathematics education plays a crucial role in shaping students› academic performance and future prospects. Unfortunately, studies indicate a consistent pattern of poor performance in mathematics across all levels of education. Data from the National Examinations Council of Tanzania over five years from 2018 to 2022 reveals an average failure rate of 80% in mathematics among secondary school students. Disparities in academic achievement are evident among regions, districts, and schools, with some consistently outperforming others. These performance gaps are often attributed to differences in learning opportunities, among other factors (Mkenda, 2022). Analysis of Certificate of Secondary Education Examination (CSEE) results highlights regions such as Songwe, Singida, Dodoma, Mtwara, and Lindi as consistently underperforming, while regions like Dar es Salaam, Geita, and Iringa demonstrate strong performance.

Poor performance in mathematics is often attributed to various factors such as negative attitudes, lack of motivation, insufficient teachers, and ineffective teaching methods (Mkenda, 2022). The limited competence of teachers to implement Problem-Based Learning pedagogy (Kikomelo, 2024) contributes to the persistent poor performance in mathematics. Attitudinal factors also play a significant role, as students often perceive mathematics as difficult and masculine, which hinders their performance (Kinyota, 2020). Teachers[2]' diverse views on students› aptitude and the teaching-learning environment also impact their instructional behaviour and, consequently, students' learning outcomes (Mazana et al., 2020).

Despite the multifaceted nature of poor performance in mathematics, the choice of teaching methods significantly influences student engagement, comprehension, and retention of mathematical concepts (Hiebert & Morris, 2012). Traditional lecture-based instruction is known for limiting the acquisition of critical thinking skills (Smith & Wang, 2020). In contrast, collaborative and technology-enhanced strategies promote deeper understanding and improve academic performance (Freeman et al., 2014; Rachmah, 2017). However, literature shows that mathematics teachers tend to choose the traditional lecture method in favour of content coverage and time-saving, thereby limiting students' learning (Mazana et al., 2023).

A thorough analysis of the existing literature reveals a significant gap in the research on the subject at hand. For example, Mollel et al. (2022) explored the impact of a collaborative learning approach, particularly computer-supported collaborative learning, on students' understanding of mathematics. Similarly, Kasuga et al. (2022) investigated the effects of a problem-based learning approach on students' motivation in biology education in Tanzanian secondary schools. Furthermore, Michael (2023) studied the outcomes of using a participatory method on students' learning in mathematics and biology in Tanzania. Mbedule

(2020) examined the influence of teaching methods on the academic performance of secondary school students in basic mathematics in Dar es Salaam, Tanzania. Additionally, Mkimbili (2018) looked into learner-centred teaching in community secondary schools throughout Tanzania. While these studies made valuable contributions to the field, they did not specifically address mathematics teachers' understanding of the jigsaw method, which could potentially enhance its effective use and improve mathematics learning and performance among secondary school students. Therefore, reconsidering teachers'' choices of teaching strategies could have a positive impact on mathematics learning outcomes.

Jigsaw teaching strategy and mathematics learning

The literature demonstrates that optimal performance in mathematics can be attained through the implementation of cooperative learning methods (Freeman et al., 2014; Rachmah, 2017). Among the array of cooperative learning techniques available, notable examples include student teams-achievement division, team games-tournament, think-pair-share, Round Robot Brainstorming, Reciprocal Teaching, and the jigsaw method (Dhull & Verma, 2019). There are various methods within a cooperative approach including learner-centred, problem-based learning, and inquiry-based learning. These approaches position every student as an engaged and self-reliant learner, fostering a sense of accountability for their academic progress. However, among the various cooperative learning strategies, available studies have shown that the jigsaw method stands out as particularly impactful on students' learning outcomes compared to others (Rachmah, 2017; Ojekwu & Ogunleye, 2020).

The jigsaw strategy is a cooperative learning strategy that involves breaking a class into small groups, with each group becoming an expert in a specific topic or concept and then sharing their knowledge with the rest of the class (Aronson & Patnoe, 2011). The core components of the strategy, such as the initial formation of expert clusters followed by the reshuffling into mixed-expertise teams, are well known for capturing learners' diversity in learning mathematics. According to Bayraktar (2021), the effectiveness of the jigsaw strategy depends much on adherence to several principles, including having "home groups" of 3-5 students who reflect a range of abilities, determining essential topics or areas for discussion, creating "expert groups" that consist of students across "home groups" who will read the same selection and provide key questions and resources necessary for all students to learn about their topics to become "experts". However, other principles, like monitoring the discussion and guiding the proper way for knowledge sharing, which often guides normal group discussions, remain constant.

Figure 1 provides a framework for understanding how the jigsaw teaching strategy can be used in actual classrooms. Step 1 represents the home groups, which may have students ranging from 3-5 of diverse learning abilities, then step 2 shows the expert groups, which are composed of one member from each home group. However, the actual implementation and effectiveness of the method depend on various factors such as student engagement, the nature of the topics being covered, teacher facilitation, and resource availability.

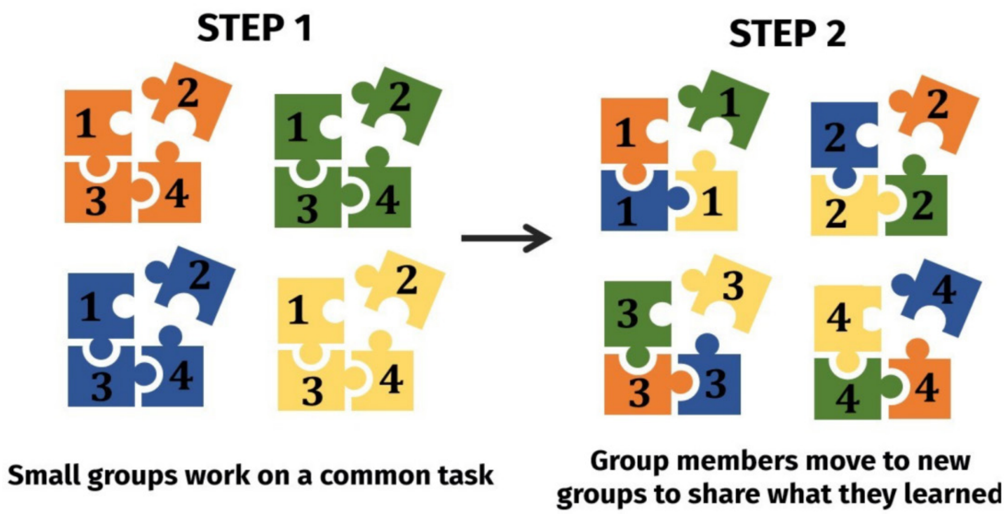

Figure 1: *A framework for the use of jigsaw strategy in teaching*

Source: Bayraktar (2021)

Here is an example of how the jigsaw method could be applied to teach a Form Two class of 16 students about simultaneous equations using four different methods. The students will learn how to solve simultaneous equations through substitution, elimination, graphical, and matrix methods. The teacher will divide the students into four groups, each consisting of four-members. Each group will be given the same set of simultaneous equations to solve using one of the mentioned methods. After solving the equations, the groups will be reshuffled into expert groups, with each group containing one member from the original groups (A, B, C, D). Each expert will then teach their method to the other members, ensuring that everyone gains knowledge of all four methods of solving simultaneous equations. The jigsaw strategy has been regarded as a powerful tool in helping students grasp challenging concepts in mathematics and other subjects (Costouros, 2020). Research shows that using the jigsaw method can improve students' achievement, motivation, social relations, and academic self-esteem (Drouet et al., 2022). Ural et al. (2017) also found that the jigsaw method can enhance students' motivation to learn.

Berger and Hänze (2015) demonstrated that the jigsaw method can significantly impact the quality of teaching and intrinsic motivation to learn-in the field of physics. They found that the jigsaw method helps learners grasp complex content more easily compared to other strategies. Furthermore, Blajvaz et al. (2022) reported a significant improvement in students' physics achievement, metacognitive awareness, and motivation after implementing the Jigsaw technique. This suggests that integrating the jigsaw method into daily school practices at the lower secondary level could be highly beneficial for education. Studies indicate a favourable influence of the jigsaw method on students' social relations (Oakes et al., 2019; Costouros, 2020). Similarly, Theobald et al. (2017) observed that effective implementation of the jigsaw method resulted in enhanced interpersonal attitudes and empathy among students. Additionally, Mohamadlou et al. (2021) reported a significant influence of the jigsaw method on students' sense of social skills and their connectedness to school.

The jigsaw strategy in mathematics has been shown to enhance self-esteem and academic achievement. A study by Berger and Hänze (2009) in secondary schools found that students with lower academic self-concepts felt more competent with the jigsaw method compared to traditional instruction. Direct engagement in group activities allows students to freely exchange ideas (Drouet et al., 2023) learning communities and collaborative groups in the classroom (Mbacho, 2013). The jigsaw approach promotes creativity and critical thinking, leading to improved academic performance (Aprili & Amelia, 2022; Turgut & Turgut, 2018). Mbacho (2013) observed significant improvements in students' math scores after teachers'' were trained in the jigsaw method. However, the benefits of the jigsaw strategy can be influenced by factors such as teachers' readiness, availability of resources, classroom conditions, content complexity, and students' educational levels (Smith & Wang, 2020; Inan & Dogan, 2016; Wei et al., 2023). Teachers' positive attitudes towards cooperative teaching strategies may be hindered by limited knowledge, affecting effective implementation (Gillies & Boyle, 2010). Ineffective implementation can have negative effects, especially for students with lower abilities. Group composition is crucial, as students of varied abilities can support each other. O'Leary et al. (2019) noted that students with low abilities may feel isolated and confused when using the jigsaw method. Studies have also shown negative effects on social self-esteem (Roseth et al., 2019) and insignificant impacts on intrinsic motivation (Costouros, 2020).

Based on these diverse findings, it can be argued that a significant portion of the surveyed studies indicates the effectiveness of the jigsaw method in enhancing students' social relations and fostering connections not only among peers but also within the broader school community. Nevertheless, careful consideration is warranted regarding challenges related to students' ability to effectively engage with others when utilizing the jigsaw method, ensuring that all students have equitable opportunities to grow socially and academically.

Methodology

Study approach and design

The study utilised a qualitative research approach with a case study design to explore mathematics teachers› comprehension of the jigsaw method in teaching and learning mathematics. This approach was deemed valuable as it considers teachers' real-life experiences to establish a profound understanding of their proficiency in using the jigsaw strategy effectively in mathematics education. Specifically, the study employed a case study design, focusing on individual mathematics teachers and the schools where they work. The research investigated their proficiency in utilising the jigsaw collaborative method and how they acquired this proficiency. By treating individual teachers and their schools as cases, the study captured the complex nature of teachers' proficiency in using the jigsaw method. This approach ensured a comprehensive understanding of teachers' proficiency in the jigsaw strategy and how they acquired the necessary skills to enhance mathematics performance in Tanzania.

Participants and sampling procedures

The study utilised a purposive sampling technique to select six secondary schools within Mtwara municipality based on their performance in national secondary education examinations. Consequently, the poorly performing schools were sampled. All mathematics teachers from the selected schools were purposively included in the study. Ethical standards were adhered to by obtaining a permit letter from the Vice Chancellor to connect with the regional administrative office in Mtwara and the selected school management. Pseudonyms were used for schools and participants to maintain confidentiality. Participants are identified by their school and a corresponding number in the findings. As such, information on the socio-demographic characteristics of the participants, including sex, level of education, and teaching experience was captured. In total 10 mathematics teachers were engaged in the study. The majority of participants were males (8) while only two (2) were females, highlighting the prevailing gender bias towards mathematics. Furthermore, seven (7) teachers held bachelor's degrees, whereas only three (3) had a Diploma in education. The teachers also had varying years of experience in teaching mathematics, with the highest experience falling within the 13-15 years range, represented by a single teacher. The majority of teachers (3 each) had experience in the 4-6 – and 7-9-years range. In addition, two (2) teachers had taught mathematics for 1-3 years, and only one teacher had experience in the 10-12 years range.

Data collection methods

The study primarily utilised semi-structured interviews to gather data from mathematics teachers. A set of questions was designed to probe teachers' understanding of the jigsaw strategy in teaching mathematics. In total, 10 face-to-face interview sessions were conducted, one with each mathematics teacher. These interviews took place within the school premises during regular working hours. Each session lasted between 20 to 30 minutes, allowing for a comprehensive exploration of the topic. Here are some of the questions asked during interviews: have you ever heard about the jigsaw collaborative teaching strategy? And please, can you explain what you know about the jigsaw collaborative teaching strategy?

Data analysis process

The researcher utilised a thematic analysis technique involving inductive-deductive coding to analyse the data. The process was conducted manually by reading the transcripts multiple times to become familiar with and understand the emerging themes from the data. Initially, the process resulted in 12 codes, as shown in Table 3, which were then analysed deductively based on the existing categories of understanding. According to Braun and Clarke (2006), the inductively identified codes must be interpreted and assigned to deductively developed themes. Therefore, related codes with their respective voices were grouped to inform each pre-established theme, as presented in the study findings. Table 2 displays the themes generated along with their corresponding codes observed from the data.

Table 2

Criteria for Data Analysis and Themes Development

Themes	Codes	No. participants
1. Good understanding of the jigsaw	▪ Teachers never heard about it. ▪ Teachers clearly illustrate a step-by-step implementation of the Jigsaw strategy. ▪ Teachers clearly describe the advantages and disadvantages of the Jigsaw strategy. ▪ Teachers have employed it in teaching but not regularly.	3

Themes	Codes	No. participants
2. Partial Understanding of the jigsaw	▪ Teachers are aware of the jigsaw strategy. ▪ Teachers fail to articulate the basic principles guiding the strategy such as the role of different group dynamics and interdependence. ▪ Teachers have misconceptions about the strategy confusing it with other collaborative approaches. ▪ Teachers try to describe but confuse the steps for the implementation of the Jigsaw strategy. ▪ Lack of confidence to employ the strategy in teaching mathematics.	5
3. Lack of understanding of the jigsaw	▪ Teachers never heard about the strategy ▪ Teachers knew nothing about the strategy ▪ Teachers never thought of employing the strategy in teaching.	2

Findings and Discussion

This section presents the findings based on the established research questions. The research questions focus on teachers' comprehension of the jigsaw cooperative learning strategy and how they gained this knowledge. The premise was that teachers' grasp of the jigsaw strategy in teaching mathematics has implications for its implementation and, ultimately, students' comprehension of mathematical concepts and enhanced student academic performance.

Mathematics teachers' understanding of the jigsaw teaching strategy

This section discusses mathematics teachers' comprehension of the jigsaw cooperative teaching strategy in mathematics instruction. Understanding the strategy is crucial as it determines whether teachers can effectively utilize it to maximize its benefits for mathematics learning. An analysis of interview data revealed three themes regarding teachers' understanding of the jigsaw strategy: a majority (5) had limited understanding, some (3) had a good understanding, and a minority (2) did not understand anything. The findings are presented below along with relevant quotes.

Good understanding of the jigsaw method

The study findings highlight that only three (3) participants demonstrated a thorough understanding of the jigsaw strategy. This particular group of participants confidently articulated a step-by-step implementation of the strategy without hesitation. The following quotes substantiate the argument:

> The method is being done in steps. First, you need to have tasks on a certain topic, say some questions; For example, Mathematics

> questions which need to be solved by different methods. Then you create home groups by asking students to count numbers say one up to three. Thereafter, members from the home group are asked to create an expert group in which they are asked to employ one of the methods to solve the same questions. Every member of the expert is required to understand and become an expert in that method. Then the members from the expert group are asked to go back to the home group and teach the rest members of the home group what they learned. The tasks are displayed around the classroom for others to view and learn more (MT1, School E).

Another participant had this to say concerning the jigsaw method:

> In jigsaw, two groups are created, first the home and the second the expert group. You may have several questions and each of these questions will be solved in the expert group. Then members of the expert group joined back to the home group with their expertise and shared with their fellows. Thereafter they can share with the rest of the classroom members (MT 2, School E).

The findings show that some mathematics teachers possess a good understanding of implementing the jigsaw method, highlighting several key impressions. Mathematics teachers who demonstrate proficiency in implementing the jigsaw method likely exhibit strong planning skills. Teachers with a thorough understanding can effectively organise content into manageable segments and select appropriate materials to facilitate student learning. Hobson et al. (2009) suggest that the level of teachers' pedagogical knowledge is an important determinant of quality teaching in the classroom. Teachers with a good understanding of the jigsaw collaborative strategy are adept at guiding student discussions and fostering productive group interactions during jigsaw activities. Their facilitation skills enable them to address misconceptions, clarify complex concepts, and maintain a supportive learning environment. A good understanding of the jigsaw collaborative teaching strategy can also lead to its effective implementation, promoting collaboration and active engagement among students while fostering a sense of ownership for their learning.

Literature shows that; teachers who understand the jigsaw strategy can easily design and facilitate collaborative learning experiences that promote student engagement and achievement in mathematics (Drouet et al., 2023). The benefits of teachers' understanding in realising the benefits of collaborative strategies were also evident in Turgut and Turgut's (2018) study, which reported that competent teachers in collaborative techniques managed to help students develop interpersonal and intrapersonal intelligence to have productive groups, thus having a significant impact on students' mathematics achievement in Turkey. It is difficult to experience the benefits of the jigsaw collaborative strategy on students' attitudes towards learning mathematics, academic achievement, and acquisition of collaborative skills if teachers are not proficient. Teachers with a good understanding of the jigsaw collaborative strategy can easily enhance mutual respect, cooperation, and support among students, which in turn will yield positive results in academic performance. Theobald et al. (2017) suggest that teachers' expertise in effectively structuring and managing group processes could enhance jigsaw collaborative groups, increase learning, cultivate positive attitudes toward science, and enhance social identity as a scientist in classrooms. Therefore, teachers with a good understanding of a jigsaw collaborative strategy hold promise for a bright future in mathematics learning and students' academic performance.

Partial understanding of the jigsaw strategy

The interview data shows that many interviewed mathematics teachers (5) demonstrated a limited understanding of the jigsaw teaching strategy. This was reflected in their responses, which showed awareness of the jigsaw strategy but a deficiency in understanding what it is and how it could be used in the teaching and learning process. Participants in this category admitted having heard about the method but had little understanding, which affected their confidence in using it in teaching. This is noted in the following quotes:

> I once heard this strategy, mh! I don't even remember at what occasion but the thing is I don't know what it entails and how it is used (MT1, School B).

> Ooh! I remember, by then when taking a diploma in education, mmh! We were exposed to many teaching strategies including jigsaw but for sure I did not understand it and since then I have never heard again about it. So, I cannot say what exactly it means (MT1, School C).

Similarly, another participant confirmed that she once heard about the strategy a long time ago. However, by then she thought it was meant for classes with few students. Therefore, she does not even remember what the strategy is all about. Here is her quote;

> …Well! About the Jigsaw method, I heard about it a long time ago. Based on what I heard is a good method of teaching mathematics however, I found it suitable for a few students thus I didn't bother

> understanding it as I am working with a large number of students (MT 2, School A).

She further added "*To be honest I don't know what is it and how to employ it because I don't normally use the method in my teaching of Mathematics* (MT 2, School A).

However, there were some participants (3) who went beyond mere awareness by demonstrating a limited understanding of the strategy. This group of participants indicated that they were familiar with the method and offered some explanation of what it is and how it could be used in teaching mathematics. However, their step-by-step explanations of the method lacked clarity, as seen in the following quotes.

> When conducting a jigsaw, several steps need to be followed. If I remember well first, you form some groups in the classroom during the questions. Then you give them different questions to solve in their groups. Thereafter, one member from each group is asked to solve the question in front of the others (MT1, School D).Top of Form

Other participants added

> From what I know the use of the jigsaw method, first of all, requires a teacher to divide the students into expert groups where you give them questions to be solved. It can be three, four or five questions. Then you ask them to solve the questions. From there, you create what we call home groups from which students from expert groups will go and share their solutions with each of the home groups created (MT 2, School B).

> In my understanding, the Jigsaw method is not that much different to group discussion as it is done by creating groups of a few students and giving them questions or some mathematical problems, then each group is assigned a leader who will then present in front of others what they have discussed (MT 2, School D).

The quotes suggest that most teachers are aware of the jigsaw teaching strategy, but lack a comprehensive understanding of its implementation, potential uses, and benefits in teaching mathematics. This lack of understanding may hinder their readiness to utilise the strategy effectively to enhance students' understanding of mathematics. Consequently, teachers may continue to rely on traditional teacher-centred approaches, leading to persistent poor performance in mathematics. This aligns with the findings of Gillies and Boyle (2010), who highlighted the challenges associated with implementing collaborative teaching approaches due to insufficient knowledge. Teachers with incomplete knowledge may struggle to design and structure jigsaw activities that align with the specific learning objectives and content standards of the mathematics curriculum. Without a thorough understanding of how to adapt the method to suit mathematical concepts and skills, teachers may implement the strategy superficially or in a disjointed manner, diminishing its effectiveness as a pedagogical tool.

Similarly, O'Leary et al. (2019) found that teachers with limited knowledge of the jigsaw strategy may ineffectively implement it, leading to students feeling isolated, confused, and struggling to navigate assigned tasks. This ineffective implementation can result in superficial learning, missed opportunities for meaningful interaction, and limited conceptual understanding of mathematical concepts. As a result, students may not develop the necessary skills associated with collaborative strategies like jigsaw, contributing to persistent academic struggles. The findings also support Mkenda's (2022) assertion that the use of ineffective teaching methods can lead to ongoing poor performance. Therefore, the mathematics teachers' limited understanding of the jigsaw strategy can have a detrimental impact on student learning outcomes, affecting both individual students and broader national and international goals related to mathematics achievement.

Lack of understanding of the jigsaw

The findings also revealed that two participants were completely unfamiliar with the jigsaw collaborative teaching strategy. These individuals had more than 10 years of teaching experience. Participants in this category confirmed that they had never encountered the method before and were not aware of its practice. Here are the quotes to support the argument; "uuuh! Jigsaw. (*silent*)…. you said a teaching strategy? *I don't think to have ever heard about it. Honestly, I know nothing about it*. (MT1, School F).

Similarly, a teacher from school A had this to share which reflects a lack of understanding of the jigsaw collaborative teaching strategy;

> mmh! Jigsaw aaah! A teaching strategy? I remember learning different teaching strategies during my teacher education programme like lectures, discussions, projects, problem solving etc but this was not among them, so frankly speaking I don't think I can tell what is it (MT1, School A).

Research studies have consistently shown that the jigsaw cooperative strategy is more beneficial than other learner-centred strategies (Aprili & Amelia, 2022; Mohamadlou et al., 2021; Theobald et al., 2017). The absence of mathematics teachers who are knowledgeable about this strategy may have led them to use ineffective teaching methods, resulting in persistently poor performance. Hiebert and Morris (2012) suggest that the failure to select and implement relevant and effective strategies for mathematics learning can impact students' understanding and ultimately lead to poor performance. Therefore, the poor performance in mathematics in the sampled schools can be partly attributed to the lack of understanding of the jigsaw strategy among mathematics teachers.

The findings indicate that many mathematics teachers do not have a thorough understanding of the jigsaw method. Teachers who lack comprehension of the jigsaw method may encounter challenges in effectively implementing it in their classrooms. This could result in activities that are disjointed or poorly structured, reducing the potential benefits of cooperative learning for students. Cooperative learning strategies like the jigsaw method aim to promote the development of crucial skills such as communication, teamwork, and problem-solving. Mbacho (2013) argues that by employing the jigsaw approach, learning communities and collaborative groups can be nurtured within the classroom, creating a more conducive environment for students to grasp mathematical concepts. In addition, Smith and Wang (2020) put forward that teachers' limited understanding of teaching strategies including jigsaw that can suit students' intellectual levels and enhance the understanding of the subject has enormously contributed to underachievement in mathematics examinations. Thus, when teachers lack understanding of how to leverage these methods, students may not have the opportunity to fully develop these skills, impacting their overall academic growth and preparedness for future challenges.

Sources of jigsaw understanding among mathematics teachers

The researchers were also curious to know how individuals with a good and partial understanding of the method learned about the jigsaw strategy. This information is valuable as it can guide future efforts to ensure that all mathematics teachers are familiar with collaborative strategies, including the jigsaw method. Participants shared various sources of their understanding, with some having multiple sources contributing to their knowledge. Here are the sources of jigsaw understanding among mathematics teachers:

Pre-service training

Analysis of the interviews shows that five (5) out of eight participants with a good and partial understanding of the jigsaw strategy confirm to have learned it during their pre-service teacher training. The following quotes explain:

> During my teacher education programme, I was taught about it,

> then I got to know it better as one of my tutors who was teaching Physics used it frequently. He used to keep us in groups with diverse tasks (MT2, School B).

> I remember when I was taking my degree in education our methodology teacher mentioned the jigsaw as one of the leaner-centred strategies The problem is he did not get into the details of how the method is being implemented (MT1, School D).

In-service training

On the other hand, a total of five participants also mentioned that they had heard about the jigsaw method during their in-service training. Two types of in-service training were confirmed by teachers to have exposed them to the jigsaw strategy: one was out-of-school training, and the other was in-school training or mentorship. Those who had the opportunity for out-of-school training mentioned that jigsaw was one of the topics covered during a training session organised for science teachers within the district with the aim of building capacity to teach science subjects and improve performance. Here are the quotes to support this argument:

> I once attended a seminar that was organised by one of the NGOs. The seminar was for all science subject teachers. During that seminar, we were taught about how to employ learner-centred strategies including the jigsaw method and the gallery work (MT2, School E).

Another participant added,

> I got to know about the jigsaw method during the seminar that was organised by the municipal council. The seminar was organised for capacity building among mathematics and physics teachers During that seminar among other issues we were exposed to different potential teaching strategies including jigsaw that can enhance learning (MT2, School D).

In addition to that, two participants confirm to have gained an understanding of the jigsaw collaborative method through school-based in-service training. For instance, during a visit to one of the schools, a teacher mentioned that they regularly engage in discussions with their colleagues about effective methods for teaching mathematics and other science subjects. This is exemplified by the following quote:

> We have created our own culture here in our school. Every Friday because it is a short working day we spare like an hour and have to assess what we have done during the week and explore some

> challenges we encountered and how to mitigate them. It was during one of the meetings that one teacher shared about the use of jigsaw and how it worked in her lessons, I was interested and keen to understand it better (MT1, School B).

Self-study

The research findings show that two out of eight participants are self-motivated to grow professionally resulting in understanding the jigsaw method. One participant expressed that he was very disappointed seeing a persistent poor performance in mathematics for almost three years consistently so he had to find how to address the problem. The specific teacher had this to share:

> After being employed I noticed poor performance in mathematics at my school, this was a great disappointment and I was curious to know why and how I could change the situation. I started reading and updating myself on issues relating to the proper teaching of mathematics and one day I visited a certain website which had issues related to the effective use of jigsaw for better learning, it showed step-by-step how to implement the jigsaw method (MT1, School E).

The other participant shared that she once found a fellow mathematics teacher teaching using an interesting strategy. She was attracted and interested in the way the students were busy engaging in the lesson. Therefore, she was curious to know the method and asked a colleague to help her understand it. Here is the quote to substantiate the argument;

> I had no idea about the Jigsaw method until one day when I was just passing outside the class where my colleague was teaching and found him teaching using a very interesting strategy with high student engagement in the lesson. Then I asked my fellow teacher about the strategy and how I could utilise it in classrooms… (MT1, School C).

It is evident from the findings that teachers' understanding of the jigsaw collaborative teaching strategy is directly linked to what they learn during pre-service teacher training, in-service training, and self-study. Pre-service teacher education serves as the foundation for teachers' classroom practices. However, the knowledge gained during pre-service teacher education may not be effective in a changing world without continuous in-service training and personal efforts. Therefore, there is a significant need for teachers to update their knowledge of teaching strategies through in-service training and personal initiatives. Collaboration among educators, such as through lesson study, co-teaching, and professional learning communities, enables teachers to share best practices, reflect on teaching experiences, and address common challenges (Abbas, 2024). School-based in-service training offers opportunities for peer learning and professional growth. Workshops for mathematics teachers can enhance understanding of the jigsaw strategy, leading to improved student performance. Due to financial constraints, the focus is on organising school-based in-service seminars rather than larger training programs, allowing experts to share experiences, discuss problems, and collaborate on solutions.

In a study in India, Grover (2023) found that in-service training significantly improved teachers' professional capacities, competencies, and teaching skills, leading to better student academic performance. However, Hobson et al. (2009) warned that school-based mentoring may not always be effective for new teachers, as some mentors may promote outdated teaching methods. It is important to balance out-of-school training with school-based and individual efforts for optimal learning outcomes. Teachers who are motivated to improve their teaching practices can engage in self-directed learning, such as exploring new teaching strategies like the jigsaw method. This intrinsic motivation to grow professionally is linked to better decision-making, career exploration, and goal-setting. By actively seeking opportunities to enhance their skills, teachers contribute to a culture of continuous improvement and ultimately improve students' mathematics performance in their schools and districts.

Conclusion and Recommendations

In conclusion, the study reveals a significant disparity in mathematics education with many teachers lacking a strong grasp of the jigsaw method. This highlights the urgent need for targeted interventions and support to enhance teachers' cooperative learning skills. The implications are profound, as students may miss out on collaborative learning opportunities and a deep understanding of mathematics concepts. Misconceptions may persist, and achievement gaps could widen without the effective use of cooperation. The study shows the importance of various initiatives, such as pre-service training, in-service support, and personal efforts, in improving teaching proficiency with jigsaw strategy and student performance in mathematics.

To address this issue effectively, school management, educational leaders at ward and district levels, and the Ministry of Education Science and Technology should provide regular in-service training for mathematics teachers on collaborative teaching methods, focusing on the jigsaw technique. This training will enhance teachers' skills and confidence in using collaborative approaches, leading to increased motivation for both teachers and students in mathematics instruction.

Mathematics teachers can also engage in peer collaboration activities like lesson study groups and collaborative planning sessions to share ideas, and best practices, and receive feedback on implementing the jigsaw method. Additionally, the teachers' continuous professional development (TCPD) programmes can be enhanced to support teachers in fostering a culture of reflection and improvement through an online learning management system. This will enable teachers to collaboratively address challenges, explore new teaching approaches, and continuously update their knowledge. On the other hand, further research is needed to explore the implementation and impact of the jigsaw strategy on mathematics performance and also assess students' collaborative skills for effective use of the jigsaw method in Tanzania.

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Integrating Neuroeducation Principles into Mathematics Instruction in Tanzanian Public and Private Secondary Schools

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Abstract

Integration of neuroeducation principles into mathematics instruction can significantly improve learning outcomes in Tanzania. Despite technological advancements, secondary schools face challenges in mathematics, necessitating effective teaching methodologies tailored for a digital landscape to enhance student performance. A qualitative study was conducted involving three mathematics teachers from public and private secondary schools in Iringa Municipality to explore their teaching practices in the integration of neuroeducation principles. This study explored the integration of Neuroeducation Principles in mathematics instruction. Data were collected through semi-structured interviews, lesson observations, and document analysis. The findings highlighted discrepancies between teachers' claimed understanding and actual teaching practices in the integration of predominantly traditional neuroeducation principles. Challenges like large class sizes and inadequate resources limited interactive strategies. Recommended interventions include providing sufficient materials, integrating technology, and improving professional development. The study provides insights for policymakers and educators on integrating Neuroeducation Principles with digital technologies to create an engaging, and inclusive mathematics instruction.

Keywords: *neuroeducation, mathematics instruction, Tanzania, teaching strategies*

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Introduction

Enhancing mathematics education in the digital age is a pressing global challenge, particularly in developing countries like Tanzania. Mathematics education is vital for fostering critical thinking, and problem-solving skills, and preparing students for future career opportunities in an increasingly technological world (Boaler, 2016). However, Tanzanian secondary school students often exhibit difficulties in mathematics subjects, leading to poor performance and diminished interest in scientific inquiry (Kyaruzi et al., 2019). This study investigates the integration of neuroeducation principles to address these challenges, providing a mathematics foundation for effective teaching strategies in mathematics education (Howard-Jones, 2008). Neuroeducation is an interdisciplinary field that merges insights from neuroscience, psychology, and education to enhance understanding of how students learn (Ansari et al., 2012; Carew & Magsamen, 2010). It emphasizes the importance of approaches such as active learning, multisensory instruction, and cognitive load management (Jensen, 2008). Despite its potential benefits, the application of neuroeducation principles in Tanzanian classrooms remains limited (Mazana et al., 2020).

In the context of mathematics education, traditional teaching methods often rely on rote learning and memorization, which may not cater to the diverse learning needs of students (Boaler, 2016). Through integrating neuroeducation principles, educators can create more engaging and effective learning environments that foster deeper understanding and retention of mathematics concepts. This research aims to explore how neuroeducation principles are integrated into mathematics curricula and teaching practices to enhance learning outcomes in the digital age. This study contributes to new insights that can improve mathematics education in Tanzania. By examining the integration of neuroeducation principles into existing teaching practices and identifying barriers to implementation, the findings will provide valuable data to inform educational reforms. The Ministry of Education can leverage these insights to optimize instructional strategies and address persistent challenges related to student performance. Moreover, the research aims to empower educators by offering practical recommendations tailored to the local context.

While prior studies have indicated the potential of neuroeducation to improve student learning outcomes, there is limited empirical evidence regarding its application in mathematics education at the secondary school level (Howard-Jones, 2008; Yates, 2022). This study seeks to address this gap by exploring how teachers perceive and experience the integration of neuroeducation principles into mathematics curricula and teaching practices to enhance learning outcomes in the digital age. The objectives of this study are threefold: first, to investigate how neuroeducation principles are currently integrated into mathematics curricula and teaching practices; second, to analyse the impact of these integrations on student engagement and learning outcomes in the digital age; and third, to identify the challenges and opportunities teachers encounter when applying neuroeducation principles in mathematics instruction. This research builds on existing literature by providing qualitative insights into the practical application of neuroeducation within the Tanzanian educational context (Dekker et al., 2012; Stein & Fischer, 2011).

Literature Review

Neuroeducation is a multidisciplinary field that integrates education, psychology, neuroscience, and cognitive science, aiming to enhance instructional strategies through insights into how individuals learn (Ansari et al., 2012; Carew & Magsamen, 2010). The development of brain imaging technologies, such as functional magnetic resonance imaging and electroencephalography, has been pivotal in understanding the brain's activity during cognitive tasks (de Hortega & García, 2012; Jolles & Jolles, 2021). Neuroeducation seeks to bridge the gap between neuroscience and education, employing empirical data to inform teaching techniques, curricula, and educational policies (Farah, 2010; Tokuhama-Espinosa, 2015). As a relatively nascent field, neuroeducation has initiated critical discussions among educators, administrators, and brain scientists regarding its practical applications (Howard-Jones & Washbrook, 2011). This discipline emphasizes translating scientific insights into actionable strategies, thereby improving educational outcomes and aligning practices with cognitive processes (Howard-Jones, 2014). Leveraging advances in neuroscience, neuro-education provides evidence-based insights that can transform teaching methodologies and curricular designs, thus promising to revolutionize education (Nouri, 2016). Understanding neuro-education is essential for educators and researchers seeking to explore its applications in diverse educational contexts**.**

Neuroeducation principles

Neuroeducation is an interdisciplinary approach that combines neuroscience and education to optimize teaching methods and improve learning outcomes (Howard-Jones, 2008; Howard-Jones et al., 2016). Central to neuroeducation is the understanding of how the brain learns, emphasizing the interconnectedness of social and cognitive processes crucial for knowledge construction. This approach promotes strategies such as active, collaborative, and multisensory learning, differentiated instruction, and metacognitive strategies, which are especially effective in teaching mathematics.

Active learning as a key principle, engages students in their learning process, fostering strong neural connections and enhancing memory (Jensen, 2008). Techniques like hands-on activities and group discussions deepen understanding of mathematical concepts (Fisher & Frey, 2014). The principle of ***Emotion and motivation*** underscores the importance of creating a positive emotional classroom environment, enhancing motivation through autonomy and real-life applications (Pekrun et al., 2011; Reeve, 2016). ***Timely feedback*** is crucial for guiding student progress and addressing misconceptions in mathematics (Hattie & Timperley, 2007). ***Multisensory instruction*** enhances engagement and retention by integrating various sensory modalities (Kestel et al., 2012). Effective ***Cognitive load*** management alleviates mental effort by breaking down complex tasks and using scaffolds (Sweller et al., 2011b). Finally, the Principle of ***Multiple intelligences*** encourages educators to tailor instruction to diverse learning styles, enhancing engagement and understanding across varied student profiles (Gardner, 2015; Gardner & Hatch, 1989). While strategies like active, collaborative, and multisensory learning, as well as differentiated instruction and metacognitive strategies, are indeed emphasized in the curriculum, this study explores how integrating neuroeducation principles can deepen understanding of how the brain learns and processes mathematical concepts. By examining the alignment of these principles with the latest neuroscience research, the study seeks to further enhance the cognitive engagement of students, optimize teaching practices, and contribute to more effective and evidence-based approaches to teaching mathematics in the digital age.

The field of neuroeducation, which merges insights from neuroscience with educational practices, presents a promising avenue for enhancing learning outcomes, particularly in mathematics and science education. However, while there is an extensive body of research on neuroeducation principles, including studies on active learning (example, Vavrus, 2009; Vavrus & Barlett, 2012; Mtitu, 2014) and assessment and feedback (example., Kyaruzi et al. 2009), there remains a need for more in-depth research on how these principles are specifically applied within the context of Tanzanian mathematics education. This study aims to explore how these established principles can be further integrated and adapted to local teaching practices, fostering a deeper understanding of their impact on student engagement and learning outcomes in the digital age." Existing studies often fail to address local educational challenges and cultural nuances that may affect the implementation of neuro-education strategies. Furthermore, despite theoretical support for neuro-education principles, there is ***limited empirical research exploring how these concepts can be translated into classroom practices***. The complexities involved in practical implementations such as curriculum constraints, teacher training, and resource availability are often overlooked in current literature.

Complexity in teaching and learning mathematics

Neuroeducation principles are essential in addressing the complexities of teaching and learning mathematics, aligning instructional methods with cognitive processes to enhance educational outcomes. The intricacies of mathematics education are influenced by cultural contexts, learning styles, and educational systems. For example, in the United States, educators implement active learning strategies and multisensory approaches to engage students (Goswami, 2006). Japan emphasizes collaborative problem-solving and real-world applications, fostering a culture of perseverance (Hiebert et al., 1999). Finland's holistic approach prioritizes student well-being and motivation (Sahlberg, 2011), while Singapore's curriculum encourages connections between mathematical concepts (Kaur & Gupta, 2013). In Tanzania, challenges such as linguistic diversity and resource limitations are addressed through multisensory learning, active engagement, and technology integration (Kisanga, 2017; Chogo et al., 2017). Overall, neuroeducation provides a framework for educators to create meaningful learning experiences by acknowledging and catering to the diverse needs of students.

Integration of neuroeducation principles into mathematics instruction

The integration of neuroeducation principles into mathematics education has garnered significant attention in contemporary academic discourse, as researchers explore the potential benefits of applying neuroscience insights to enhance learning outcomes, engagement, and student motivation (Tokuhama-Espinosa, 2011; Jensen, 2008). In Africa, studies by Machumu and Mbeba (2017) and Mvududu et al. (2016) emphasize the relevance of neuroscience concepts in addressing educational challenges. However, in Tanzania, research on this integration within mathematics instruction remains limited.

Recent studies indicate a critical need to improve mathematics education in Tanzania (Mwakapenda et al., 2020; Mgaya & Mgaya, 2019). Tanzanian schools are increasingly considering Neuroeducation Principles to engage diverse learners and enhance academic performance. Although progress is being made, further research is essential to deepen understanding of these principles within the Tanzanian context. Integrating Neuroeducation Principles is expected to revolutionise mathematics instruction, providing a more innovative and fulfilling learning experience. Fischer et al. (2007) assert that this integration aligns teaching with the brain's cognitive processes, improving information retention and academic success. Howard-Jones (2014) emphasizes the creation of instructional environments that resonate with natural brain function, fostering innovation in learning.

Benefits of neuroeducation

The integration of neuroeducation principles in teaching has been shown to yield significant benefits, extending beyond traditional academic outcomes. Jensen (2008), Nouri et al. (2022), and Stein and Fischer (2011) highlight that these principles facilitate the development of critical cognitive skills and create engaging, nurturing learning environments. Jensen (2008) emphasizes that aligning educational settings with cognitive and neurological processes enhances student engagement and fosters a positive atmosphere for learning. Nouri et al. (2022) further assert that applying neuro-education principles equips students with essential skills such as analytical thinking and problem-solving, which are vital for academic success. Stein and Fischer (2011) underscore the importance of these principles in providing students with cognitive tools that enhance traditional learning while promoting transferable skills applicable across various domains. Collectively, this evidence supports the notion that neuro-education principles not only improve educational practices but also prepare students for future challenges. The continuous application and understanding of these principles represent viable strategies for enhancing student outcomes and raising overall educational standards as the field of neuro-education evolves.

Barriers to integration of neuroeducation into mathematics instruction

The integration of neuroeducation principles in mathematics education faces several challenges that require careful attention. Ethical concerns arise, especially regarding brain imaging technologies, where issues of privacy and consent must be navigated (Vroom, 2019). Additionally, interdisciplinary complexity complicates collaboration between educators and neuroscientists, necessitating effective communication to bridge diverse methodologies (Øland et al., 2022). Practical implementation is also challenging, as translating neuroscientific insights into effective teaching strategies requires meticulous planning within educational constraints (Haggard, 2008). Furthermore, individual variability among learners presents obstacles; diverse cognitive profiles and learning styles make it difficult to tailor neuroeducation strategies for equitable outcomes (Borghi & Fini, 2019). Limited understanding of neuroscience, being a developing field, adds to these challenges (Farah & Newman, 2010). Lastly, the gap between research findings and classroom practice hampers the effective application of neuro-education principles, highlighting the need for ongoing dialogue among educators, neuroscientists, and policymakers to navigate these complexities and enhance mathematics instruction.

Methodology

Research paradigm, approach, and design

This study adopted a constructivist paradigm, emphasising understanding how teachers integrate neuroeducation principles into mathematics instruction. Constructivism posits that knowledge is constructed through experiences and reflections (Creswell, 2013), valuing subjective interpretations and the dynamic interaction between teachers' prior knowledge and neuroeducation principles. This approach encouraged dialogue and collaboration with participants to co-construct knowledge, providing rich insights into the integration process. Qualitative methodologies were employed to gather data within classroom settings, making them ideal for exploring unknown factors and diverse perspectives. This interpretive and descriptive approach recognises multiple subjective realities connected to specific contexts (Cohen et al., 2017), allowing for an in-depth investigation of integrating neuroeducation principles into Tanzanian mathematics classrooms.

A case study design was utilised, providing a robust framework for detailed exploration and analysis (Creswell, 2021). The design facilitated data collection and evaluation of neuroeducation concepts within real-world settings in two secondary schools. Multiple data collection methods ensured a comprehensive analysis (Yin, 2009), essential for understanding the complexities of integrating neuroeducation principles into mathematics instruction.

Research setting and participants

The study was conducted in a public and a private secondary school in Iringa Municipality, Southern Tanzania, to provide a comprehensive view of how neuroeducation principles are implemented across different educational contexts. By considering schools with varying socioeconomic backgrounds such as infrastructure, student demographics, teacher qualifications, parental involvement, extracurricular opportunities, and learning environments, the research explored the challenges and benefits of implementing these principles, incorporating a comparative analysis of their integration.

A total of 135 participants were involved, including 36 Form I students, 98 Form III students, and three mathematics teachers. Teachers were purposefully selected due to their critical role in curriculum implementation. The sample included two mathematics teachers from Form III and one from Form I. Teachers were selected purposefully based on their involvement in teaching mathematics and their availability for the study. Including one female teacher aimed to provide gendered perspectives in teaching practices. The gender imbalance resulted from the limited availability of female teachers in the selected schools.

Students were indirectly involved in the study, with their engagement and interactions analysed during lesson observations. This approach provided essential context to evaluate teaching strategies without directly involving students as participants. Qualitative research was prioritized to provide detailed insights into teachers' experiences and practices, enhancing the understanding of neuroeducation principles' application. Despite practical constraints, the strategic selection of teachers from different classes and schools enriched the diversity of perspectives, contributing to a thorough exploration of the challenges and successes in implementing these principles.

In addition to interviewing the teachers, lessons in Form I and Form III were observed to examine how neuroeducation principles are integrated into mathematics education. Observations were limited to avoid disrupting the regular class activities of Form I and III students, who were not involved in national examination preparations and provided essential insights into students' experiences with neuroeducation-based teaching methods. Semi-structured interviews with mathematics teachers complemented the observations, ensuring a well-rounded data collection approach that captured teacher perspectives.

Methods of data collection

Data collection involved semi-structured interviews with three mathematics teachers, aimed at gaining in-depth insight into their experiences, challenges, and perceptions regarding the integration of neuroeducation principles in mathematics teaching (Alshenqeeti, 2014). Each interview lasted one hour, allowing for comprehensive discussions. Responses were recorded using a smartphone audio recorder, with recordings securely stored for analysis.

Classroom observations were conducted to investigate the teaching environment and dynamics. Observations were carried out in three mathematics lessons—one from Form I and two from Form III—each lasting 40 minutes. Key components analysed included the integration of neuroeducation principles into mathematics instruction, the use of active, multisensory, and collaborative learning strategies, the application of differentiated instruction, and the implementation of metacognitive strategies. The observations aimed to develop a nuanced understanding of how neuroeducation principles were applied in real-world teaching contexts.

Document analysis involved examining various educational documents to understand the integration of neur oeducation principles. This included education policy documents, teacher curriculum guidelines, lesson plans, and teaching materials, providing context for the systematic integration of these principles within the curriculum.

Data analysis

Data analysis was conducted using thematic analysis to identify patterns, themes, and categories related to the integration of neuroeducation principles in science education. Following Creswell's (2013) approach, manual transcription of interviews and observations ensured accuracy. Transcriptions were reviewed multiple times to gain a deeper understanding, with keywords and phrases highlighted to create codes and categorize information based on research questions. Repetitive ideas, expressions, and perspectives were identified and merged into coherent themes, presented narratively with visual aids for enhanced understanding.

Ethical issues

To uphold ethical standards, a researcher secured a research permit from the Regional Administrative Secretary (RAS) of Iringa, which was granted for one month for the designated study sites. The permit was distributed to the Municipal Educational Director (MED) and the Heads of Schools, who facilitated introductions to the selected teachers and scheduled data collection appointments. The participants' consent was obtained by informing them about the study's purpose and their rights. Confidentiality was also prioritised by employing pseudonyms to protect their data. As noted by Arifin (2018), safeguarding human subjects in research requires adherence to appropriate ethical standards.

Findings

Demographic Profile of Participants

The inclusion of the demographic profile of participants provides context for understanding the perspectives and experiences shared by the participants. In qualitative research, individual backgrounds, such as teaching experience, educational qualifications, and career stages, play a critical role in shaping how participants perceive and implement educational principles. This section helps in interpreting the diverse viewpoints offered by teachers and the observed classroom dynamics, offering a comprehensive understanding of how neuroeducation principles are integrated into mathematics instruction. The study involved three mathematics teachers who provided rich insights into their demographics and experiences.

Teacher AY/19 is a thirty-three-year-old male with three years of teaching experience and a degree in education. As a relatively early-career educator, he offers perspectives on the challenges faced by new teachers in implementing neuroeducation principles. His emphasis on collaboration suggests openness to modern pedagogical approaches.

Teacher ML/19 is a forty-one-year-old female with fifteen years of teaching experience and a diploma in education. With over a decade of teaching, she provides practical insights into the challenges and benefits of integrating neuroeducation principles, focusing on creating a positive learning environment.

Teacher MY/25 is a fifty-four-year-old male with thirty-three years of teaching experience and a degree in education. His long tenure allows him to offer a historical perspective on changes in teaching methodologies, with an emphasis on fostering critical thinking.

Observations in the schools revealed varied levels of student engagement. In School H's Form One, thirty-six students exhibited passive engagement, while Form Three C's thirty-eight students showed disorganisation and preferred chorus responses. In School M's Form Three, fifty-eight students were notably passive, with some even sleeping during class. Also, in School H's Form Three, forty-two students demonstrated low participation, frequently relying on the teacher for guidance without initiating responses. Moreover, in School M's Form One, forty-five students appeared disengaged, often distracted and less responsive to interactive activities.

Teachers' perceptions of neuroeducation

The investigation into teachers' perceptions of integrating neuro-education principles in mathematics education revealed varied attitudes, categorized into three primary themes: enthusiasm, scepticism, and confidence. Teachers expressed varying degrees of enthusiasm towards the integration of neuroeducation principles. For example, Teacher AY/19 believes neuroeducation principles positively impact mathematics teaching by developing student interest and engagement, emphasizes the importance of collaborative learning for active engagement, advocates for comprehensive training for teachers in neuroeducation principles and stresses the role of neuroeducation in providing quick feedback on the learning process. This was evident through a statement below:

> Neuroeducation principles have a positive impact on teaching mathematics. First helps to develop student interest in learning mathematics, when teachers use collaborative methods of learning, makes learners active and engage fully in the learning process. This collaborative learning will help those who do not love mathematics to love it. Also, helps a teacher to get quick feedback about the effectiveness of the learning process because learners are fully engaged in the learning process. A teacher can also change his/her teaching style depending on the mood and nature of the learners (Teacher AY/19, Interview, 19.09.2023).

Confidence, the level of confidence in neuroeducation principles varied among the teachers. For example, Teacher ML/19 expressed confidence and sees neuroeducation principles as beneficial for improving mathematics performance and fostering a positive attitude. Emphasizes the importance of policymakers promoting neuroeducation, incentivizing innovative teaching methods, and providing professional development resources. This is proven by the statement,

> The principles are good in improving mathematics performance because help in informing strategies to enhance student engagement

> and motivation in mathematics. Creating activities that align with the learner's ability and find intrinsic rewards can foster a cheerful outlook towards mathematics. They also help create a positive and supportive learning environment in mathematics classrooms that can help reduce anxiety and stress, promoting better cognitive functioning and student interest in learning mathematics. Also, they promote memory and retention of mathematical concepts since learners are fully engaged in the learning process (Teacher ML/19, Interview, 19.09.2023).

In contrast, Teacher MY/25 focuses on developing critical thinking and problem-solving abilities in learners through collaboration. Stresses the need for assessment methods aligned with neuroeducation principles and training teachers on their application. Teachers MY/25 stated that:

> Critical thinking and problem-solving abilities to learners, normally when learners in discussion share ideas and challenge each other, they develop thinking abilities. Also, they develop an interest in learners to love mathematics, when learners collaborate, and help those who have anxiety to reduce it (Teacher MY/25, Interview, 25.09.2023).

Also, Teacher-ML/19 showcased confidence in neuroeducation principles, emphasising their role in improving mathematics performance and fostering a positive attitude.

Conversely, teacher MY/25 expressed scepticism, attributing declines in student performance to external factors like technological distractions: "*In previous years, we succeeded because students faced fewer distractions. Now everyone passes, diminishing the competitive learning environment*" (Teacher MY/25, Interview, 25.09.2023).

Neuroeducation principles integrated into mathematics classrooms

The findings indicate that teachers are implementing several neuro-education principles, including active learning, multisensory learning, emotional and motivational engagement, and feedback mechanisms.

Active learning

Most teachers reported using active learning strategies, such as group discussions and hands-on activities, to foster student engagement. Teacher AY/19 explained, "*I design hands-on activities that require students to engage in practical exercises* *related to the concepts being taught"* (Teacher AY/19, personal communication, September 2023). Teacher ML/19 also emphasized the importance of active learning, stating, *"I incorporate group work where students collaborate on problem-solving tasks to enhance their understanding of mathematical concepts"* (Teacher ML/19, personal communication, 2023). Additionally, Teacher ZM/22 noted, "*I encourage peer discussions and use manipulatives to help students visualize mathematical operations*" (Teacher AY/19, personal communication, 2023).

However, an analysis of lesson plans revealed that although teachers included active learning strategies, such as group discussions and hands-on activities, their execution in practice often fell short of effectively engaging students. The lesson plans outlined activities designed to promote student participation, but classroom observations indicated that these strategies were not effectively implemented. In School H's Form I, for instance, although the teacher planned a group discussion, students were mostly passive, with few actively contributing to the conversation. Similarly, in School M's Form III, despite the inclusion of group tasks in the lesson plans, students seemed disengaged, and the teacher did not facilitate meaningful interaction or ensure equal participation. Teacher MY/25 from School M observed, "*The group work is intended to make students interact, but in reality, only a few dominate the conversation, and others just listen*" (Teacher MY/25, personal communication, 2023). These observations suggest a gap in teachers' understanding of how to properly implement active learning techniques, as the intended strategies often failed to maximize student engagement in practice.

Multisensory learning

Teachers reported using multisensory experiences to reinforce concepts, although these practices were not always consistently applied in classrooms. Teacher AY/19 highlighted his use of hands-on materials, stating, "*I provide students with base-ten blocks to represent mathematical concepts*" (*Teacher AY/19, personal communication, 2023). Teacher ML/19 shared her approach, saying, "I use visual aids such as graphs and charts to help students visualize abstract mathematical ideas"* (Teacher ML/19, personal communication, 2023).

Despite these claims, classroom observations indicated a strong reliance on traditional teaching methods, with limited incorporation of multisensory activities. In School H's Form I, the lesson primarily involved lecture-style teaching, with little use of visual or hands-on materials. Students were mostly engaged in note-taking, with few interactive or sensory activities. Teacher MY/25 in School M shared, "*We try to use visual aids, but due to large class sizes and lack of resources, it becomes difficult*" (Teacher MY/25, personal communication, 2023). During an observed lesson in School M's Form III, the lesson consisted of textbook readings and oral explanations, with no attempt to incorporate tactile or auditory learning methods. Only one teacher in School H's Form I used a visual aid (a diagram) to explain a mathematical concept, but no further multisensory approaches, such as tactile or auditory materials, were included in the lesson. These observations suggest that, while some teachers intended to use multisensory strategies, their application was minimal because of classroom constraints.

Emotional and motivational engagement

Teachers acknowledged the importance of emotional engagement in fostering a positive learning environment. In School M, teachers attempted to create such an environment, but large class sizes hindered their ability to connect with students on an individual level. For example, in one observed lesson, the teacher used encouraging language, such as, "Great effort, let's keep trying." However, despite these efforts, the overall classroom atmosphere remained subdued, with many students appearing disengaged and passive. Teacher MY/25 from School M noted: "*It's difficult to manage emotional engagement with so many students; they don't get the individual attention they need*" (Teacher MY/25, personal communication, 2023).

In School H's Form I, the teacher focused on promoting a supportive environment by using phrases like "You can do it!" and "Don't be afraid to make mistakes." Despite these efforts, the emotional engagement was undermined by the teacher's reliance on traditional lecturing and lack of interactive activities. During the observed lesson, many students appeared unmotivated, and only a few actively participated. Teacher AY/19 from School H emphasized, *"Positive emotions lead to enjoyable learning experiences, fostering engagement"* (Teacher AY/19, personal communication, 2023), but classroom dynamics suggested that emotional engagement was not fully realized in practice.

Feedback and error collection

Teachers acknowledged the importance of timely feedback but faced challenges in its consistent application. In School H's Form I, feedback was typically given only at the end of the lesson after students completed individual exercises, offering limited opportunities for immediate correction. In School M's Form III, teachers expressed difficulty in providing individualized feedback due to large class sizes. Teacher MY/25 from School M stated, "*With so many students, it's hard to give personalised feedback. Some students don't even receive any feedback during the lesson*" (Teacher MY/25, personal communication, 2023).

In School H's Form III, feedback was occasionally provided during group work, but due to resource constraints, it was often limited to verbal comments. There was minimal follow-up on errors or opportunities for students to correct mistakes. Teacher ZM/22 from School M added, "*Feedback is important, but larger class sizes make it hard to keep up with every student. We often don't have time to address every error*" (Teacher ZM/22, personal communication, 2023). These challenges highlight the significant barriers posed by large class sizes and limited resources in providing timely, personalized feedback.

The findings from curriculum analysis, teaching guides, and lesson plans revealed that teachers are indeed attempting to incorporate neuroeducation principles, though the extent and effectiveness of integration vary. For instance, the curriculum documents outlined active learning strategies that align with neuroeducation principles. In the mathematics curriculum, the competence-based curriculum emphasizes "student-centred approaches" and "hands-on activities" to promote deeper learning and engagement, which reflect neuroeducation's focus on multisensory learning and active participation. In the teaching guides, there are explicit references to collaborative learning techniques, including group discussions and peer feedback, which resonate with neuroeducation's principles of social and emotional engagement.

For example, one teaching guide for Form I mathematics included a section on *"engaging students through problem-solving tasks" and "utilizing real-world applications," both of which align with neuroeducation's focus on context-based learning and emotional motivation* (Curriculum Guide, 2023). Additionally, the lesson plans reviewed often incorporated activities such as "interactive group discussions" and "hands-on problem-solving," which were intended to engage multiple senses and promote cognitive processing, a key principle of neuroeducation. "*One teacher's lesson plan for a geometry class included activities where students used physical objects (e.g., base-ten blocks) to explore geometric concepts, reflecting a multisensory approach*" (Lesson Plan, Teacher AY/19, September 2023).

However, the document analysis also highlighted inconsistencies in the actual implementation of these principles. While the documents reflected an intention to incorporate neuroeducation principles, some lesson plans lacked detailed strategies for how to fully engage students with these activities. For example, in several lesson plans, the inclusion of "group work" was mentioned, but there were few specific guidelines for how to facilitate active participation, a core aspect of neuroeducation's approach to social and cognitive engagement. Furthermore, some teaching guides mentioned "active learning techniques," but did not provide concrete examples of how to effectively implement these techniques in large class settings, where managing student engagement is more challenging. Thus, while the curriculum documents and lesson plans indicate an intention to incorporate neuroeducation principles, the actual integration is inconsistent and varies in its application across different teachers and schools.

Challenges faced in implementing neuroeducation principles

Teachers identified several challenges in integrating neuro-education principles, including a lack of teaching materials, limited technology access, poor student engagement, time constraints, and a scarcity of professional development programs.

Lack of leaching materials

Teachers highlighted the difficulty in accessing appropriate teaching materials to effectively implement neuroeducation principles. For instance, Teacher AY/19 pointed out, *"Lack of teaching aids can hinder the variety of methods to cater to student learning differences"* (Teacher AY/19, personal communication, September 2023). Specific materials that were identified as lacking included visual aids such as diagrams and charts, manipulatives like base-ten blocks or geometric shapes, and digital tools like interactive whiteboards or tablets. These materials are integral to the multisensory learning approach advocated by neuroeducation, which emphasizes engaging multiple senses to enhance cognitive processing.

For example, in the absence of physical objects like base-ten blocks, teachers found it challenging to help students visualize abstract mathematical concepts, such as place value and fraction decomposition. Teacher ML/19 remarked, *"Without hands-on materials like blocks or visual aids, it's hard to make abstract concepts tangible for students. It leads to students struggling with understanding key ideas"* (Teacher ML/19, personal communication, September 2023). This lack of concrete resources can undermine the effectiveness of multisensory learning, which relies on engaging students' senses to facilitate deeper learning and retention. In schools with limited access to technology, teachers faced difficulties in incorporating digital tools to enhance student engagement and provide immediate feedback, as key elements of neuroeducation. Teacher ML/19 shared, *"We don't have enough computers or interactive platforms to make learning more interactive, and students miss out on opportunities to engage with educational apps and simulations"* (Teacher ML/19, September 2023). The lack of technology further limits teachers' ability to incorporate neuroeducation principles, such as personalized learning through adaptive platforms or real-time feedback mechanisms, which could otherwise enhance student engagement and learning outcomes.

During the classroom observations, it was evident that the lack of essential teaching aids impeded the integration of neuroeducation principles. In School H, for example, the lesson on fractions in Form I lacked visual aids such as diagrams, charts, or manipulatives like base-ten blocks or fraction strips. Despite the lesson plan indicating the use of these aids, only verbal explanations were given. In the observed Form III class at School M, the lesson on algebra was conducted without any visual aids (e.g., diagrams or graphs) or hands-on materials. The teacher relied solely on the chalkboard for explanations, and no multimedia tools such as projectors or interactive digital tools were used. This absence of teaching aids, especially in a subject like mathematics, where visual and tactile tools are essential for conceptual understanding, made it difficult for students to engage fully with the content.

Technology access

Limited access to technology was consistently identified as a significant barrier to the effective integration of neuroeducation principles. Teacher AY/19 noted, *"Limited access to technology impedes the integration of neuroeducation strategies"* (Teacher AY/19, September 2023). Classroom observations further emphasized this challenge, revealing that technology, such as digital devices, interactive tools, or multimedia resources, was largely absent in the observed lessons across both schools. In School M, no digital tools were used to support the lesson, and the teacher solely relied on a chalkboard and textbook readings. The absence of apps, videos, or interactive platforms meant that students were not exposed to the digital engagement and multisensory experiences advocated by neuroeducation principles.

Similarly, in School H, the teacher faced significant limitations in incorporating multimedia resources, such as videos or interactive simulations, which are vital for fostering deeper learning and engagement in mathematics. In a Form I lesson on algebra, for example, the teacher attempted to explain concepts verbally, without the aid of visual representations, diagrams, or digital simulations that could have reinforced the learning. Teachers expressed awareness of the potential benefits of digital tools but acknowledged that their lack of availability and insufficient training were major obstacles. As Teacher AY/19 explained, *"We know that technology can make a difference, but we simply don't have the resources or the training to effectively integrate it into our teaching*" (Teacher AY/19, September 2023).

Poor student engagement

Teachers reported significant challenges in maintaining consistent student engagement, a core element of neuroeducation. Teacher AY/19 noted, *"When neuroeducation principles are used frequently, learners develop an interest in collaborative learning"* (Teacher AY/19, September 2023). Despite this recognition, classroom observations indicated that engagement levels were often low across both schools. In School H's Form I, for example, despite the teacher's efforts to create an engaging atmosphere, many students remained passive throughout the lesson. Only a handful of students actively participated, and the overall environment lacked the energy needed for active, collaborative learning. The teacher attempted to encourage student involvement by using encouraging phrases, such as "Let's work together on this," but many students appeared uninterested and disengaged.

Similarly, in School M's Form III, the level of student engagement was minimal. During group discussions, students showed little enthusiasm and only a few contributed to the discussions. The teacher struggled to motivate students to collaborate, often resorting to more traditional methods like individual work or whole-class questioning. The lesson lacked the interactive or collaborative activities that are central to fostering deeper engagement. This reliance on traditional teaching methods, without incorporating more engaging, participatory activities, contributed to the low levels of student engagement observed in both schools. As Teacher ML/19 from School M remarked, *"It's difficult to get students to engage when they are not excited about the lesson"* (Teacher ML/19, September 2023).

Time constraint

Teachers highlighted time constraints as a major challenge when implementing neuroeducation strategies. The pressure to cover a broad curriculum in a limited timeframe often led to the prioritisation of content over teaching methods. Teacher ML/19 expressed concern, stating, *"Modern methods are time-consuming, and we struggle to maintain student interest"* (Teacher ML/19, September 2023). Classroom observations confirmed that in both schools, teachers were seen rushing through lessons, with little time allocated for interactive activities or group work. In School M, the teacher was unable to incorporate feedback loops or collaborative activities because of the time limitations imposed by the curriculum. This left little room for deeper, more engaging learning experiences that align with neuroeducation principles.

Limited professional development opportunities

A significant challenge identified by teachers was the lack of professional development opportunities specifically focused on neuroeducation principles. Teacher ML/19 stressed the importance of in-service training, saying, *"Policymakers should promote neuroeducation by providing professional development resources"* (Teacher ML/19, September 2023). Classroom observations revealed that teachers were not fully equipped to implement neuroeducation strategies effectively, largely due to the absence of formal training on the topic. In both schools, it was evident that teachers continued to rely heavily on traditional teaching methods with which they were more familiar, as they had not received sufficient training to incorporate newer, research-based approaches.

In School H, for instance, teachers were observed predominantly using lecture-based methods and were not utilizing techniques related to neuroeducation, such as multisensory learning or active learning strategies. Even though teachers expressed an understanding of the benefits of these principles, their lack of training left them unable to integrate them into their lessons. In School M, the use of technology and interactive teaching methods was minimal, and teachers noted that they were unsure how to incorporate these elements into their teaching practice. As Teacher AY/19 from School M put it, *"I would like to use technology more, but I don't know how to integrate it into my lessons without proper training"* (Teacher AY/19, September 2023). These observations highlight that, without targeted professional development, teachers struggled to implement neuroeducation principles effectively in their classrooms.

Discussion of the Findings

The findings of this study provide valuable insights into the demographic profiles of the teacher participants and students, shedding light on diverse perspectives regarding the integration of neuroeducation principles in mathematics education. Three key themes emerged: *enthusiasm*, *scepticism*, and *confidence*.

Enthusiasm

Teachers exhibited varying degrees of enthusiasm towards integrating neuroeducation principles. The analysis shows that enthusiasm positively influences student engagement and learning outcomes. According to Fredrickson's Broaden-and-Build Theory of Positive Emotions (Fredrickson, 2001), enthusiasm broadens individuals' thought-action repertoires and builds enduring personal resources. In educational contexts, enthusiastic teachers have been shown to significantly enhance student motivation and academic achievement (Wang & Eccles, 2012). The data aligns with Hiebert et al. (2007), who emphasize that active and collaborative learning improves mathematics learning outcomes. Teachers' positive outlook on neuroeducation principles suggests that fostering enthusiasm through comprehensive training and professional development can enhance instructional effectiveness.

Scepticism

Scepticism emerged as some teachers attributed declining mathematics performance to external factors such as technological distractions. Scepticism, characterized by critical evaluation and the demand for evidence (Reed, 2015; Sachdev, 2019), can impact the adoption of new methodologies. Descartes' methodological scepticism (Grene, 1999) highlights the importance of evidence-based practices in overcoming doubts. This study's findings echo Shernoff et al. (2015), who noted that teacher scepticism may stem from concerns about new teaching strategies' effectiveness. Addressing this scepticism requires professional development programs that provide empirical evidence of the effectiveness of neuroeducation principles, thereby fostering trust and acceptance among educators.

Confidence

Confidence in neuroeducation principles varied among teachers. According to Bandura's Social Cognitive Theory (Bandura, 1977), self-efficacy—the belief in one's ability to succeed—is crucial for effective teaching. Confident teachers are more likely to invest time and effort into implementing new teaching methodologies, which is essential for successful integration. The findings align with Boaler (2016), who asserts that collaborative learning enhances educational outcomes, and Immordino-Yang & Damasio (2007), who emphasize the significance of socio-emotional factors in learning. Teachers who demonstrated confidence also highlighted the need for policy support, innovative teaching methods, and professional development, suggesting that these factors are critical for effective neuroeducation implementation. Document analysis indicates a notable alignment between neuroeducation principles and strategies embedded in the competence-based curriculum. Active learning, student-centred approaches, and critical thinking are central to both neuroeducation and the curriculum. Freeman et al. (2014) and Prince (2004) emphasise that active learning enhances cognitive development and mathematical understanding. Zhao (2021) and Bransford et al. (2000) further support student-centred approaches as effective for tailoring education to individual competencies. The emphasis on critical thinking aligns with Facione's (2011) definition, highlighting its importance for academic success and personal growth. The study also reveals that while teachers claim to use these strategies, classroom observations indicate a gap between intention and practice, as noted by Davis et al. (2019) and Cuban (2013).

Despite acknowledging the relevance of neuroeducation principles, many teachers struggled with implementation. This challenge is consistent with findings by Howard-Jones (2008) and Wright et al. (2019), who note that effective integration requires adequate teaching resources and training. Also, the link between student emotions, motivation, and learning outcomes is well-established (Fredrickson, 2001; Pekrun et al., 2011), yet practical application remains inconsistent. Addressing these challenges requires targeted professional development, policy support, and access to teaching resources. Darling-Hammond (2020) emphasises that such support is crucial for optimizing educational experiences, and ensuring that neuroeducation principles are effectively integrated into classroom practices.

Conclusion

This study highlights the transformative potential of neuroeducation when implemented through evidence-based, culturally relevant strategies that align with local realities. The findings underscore the current practices and challenges in mathematics education in Tanzania, particularly in the context of integrating digital technologies. Addressing issues such as resource limitations, enhancing teacher skills through targeted training programs, and promoting experience-sharing among educators are essential steps toward improving classroom practices. The integration of digital technologies within the neuroeducation framework can further enhance conceptual understanding and foster the development of 21st-century skills among students. These strategies provide significant opportunities to elevate the quality and relevance of mathematics education in Tanzania. By pragmatically incorporating neuroeducation principles alongside digital tools, more engaging and effective learning environments can be created, better-preparing students for success in an increasingly technology-driven world.

Future research directions

Future research on integrating neuroeducation principles within Tanzanian mathematics education should focus on several key areas. Longitudinal studies are crucial to investigating the long-term effects of neuroeducation on student performance and retention, providing valuable insights into the sustainability of these teaching methods. Additionally, quantitative evaluations should assess the effectiveness of neuroeducation strategies through standardized assessments and performance metrics. Comparative studies across different regions will help identify contextual factors influencing the successful integration of these principles.

Exploring effective models for teacher professional development, such as workshops and online courses, is also critical for training educators in neuroeducation. Research should examine how digital tools can enhance active and multisensory learning, gathering insights from students about their experiences to inform more responsive teaching practices. Furthermore, investigating the barriers teachers face in implementing neuroeducation and identifying facilitators for success will provide a clearer picture of the integration process. Finally, examining how neuroeducation principles can be culturally adapted will increase their relevance and effectiveness in local contexts. Addressing these areas will significantly contribute to optimizing science education in Tanzania, ultimately equipping students with essential skills for the modern world.

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Effect of Guided Inquiry-Based Experiments on Students' Acquisition of Physics Practical Skills in Ordinary Level Secondary Schools in Tanzania

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Abstract

This study investigated the effect of Guided Inquiry-Based Experiments (GIBE) on students' acquisition of Physics practical skills in Ordinary-level secondary schools in Tanzania. The study applied a quasi-experimental design and involved 82 participants. Data were collected by using the observation rubric and analysed through descriptive and inferential statistics techniques. Results indicate a significant difference in the mean scores with a large effect size for the acquisition of Physics practical skills in the domain of design, execution, analysis and evaluation between students in the experimental school and the control school. These findings suggest that GIBE is superior to Traditional-Based Experiments (TBE) in enhancing students' acquisition of practical skills in Physics. Therefore, Physics teachers should be encouraged to integrate laboratory practical activities in the form of GIBE in Physics lessons to enhance students' acquisition of practical skills which are essential attributes for effective learning of Physics.

Keywords: *acquisition, guided inquiry-based experiments, practical skills, physics learning*

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Introduction

The teaching and learning of Physics in secondary schools encompass both theoretical instruction and laboratory experiments, which are complementary in facilitating students' acquisition of knowledge and practical skills (Sudarmani et al., 2018). The science curriculum emphasizes laboratory experiments to foster students' inquiry skills and hands-on competencies, thereby enhancing their learning and achievement in science subjects (Ministry of Education and Vocational Training [MoEVT], 2007). However, in Tanzanian secondary schools, the teaching of science subjects, including Physics, remains largely reliant on the Traditional-Based Experiments

(TBE) approach (Mkimbili, 2018). During Physics practical sessions, teachers typically design step-by-step activities that require students to verify established facts, laws, and principles, demonstrate learned concepts, or prepare for practical exams, with minimal focus on fostering independent practical skills and knowledge acquisition (Mkimbili, 2018; Mkimbili et al., 2017). This reliance on TBE constrains students' ability to develop essential practical skills necessary for meaningful learning in Physics. Consequently, students have consistently underperformed in the subject due to their limited proficiency in conducting Physics experiments during practical examinations (National Examination Council of Tanzania [NECTA], 2022). An analysis of NECTA reports on students' performance in the Certificate of Secondary Education Examination (CSEE) indicates that poor performance in Physics is largely attributed to students' inability to recall and apply the requisite practical skills for conducting experiments (NECTA, 2020).

In the 21st century, there is emerging interest in using student-driven inquiry-based laboratory experiments that allow students to take ownership of their experimental work when learning physics (Cai et al., 2021). The science curriculum reforms that took place in Asian, American and African countries called for a shift from traditional-based experiments to more student-centered inquiry-based experiments (Babalola et al., 2020; Gudyanga & Jita, 2019). The use of inquiry-based laboratory activities is encouraged in science curriculum reforms to give students greater autonomy in deciding what and how physical phenomena should be investigated rather than simply following instructions written in a laboratory guide (Wilcox & Lewandowski, 2016).

Levels of inquiry-based experiments

Inquiry-based experiments are designed in four levels, ranging from highly structured to highly unstructured based on the degree of guidance that teachers offer to students (Zion & Sadeh, 2007). These levels of inquiry are confirmatory experiments, structured experiments, guided inquiry-based experiments and open inquiry-based experiments (Zion & Sadeh, 2007). They were established to guide teachers on the degree of assistance offered to students during the process of teaching Physics through laboratory work (Figure 1).

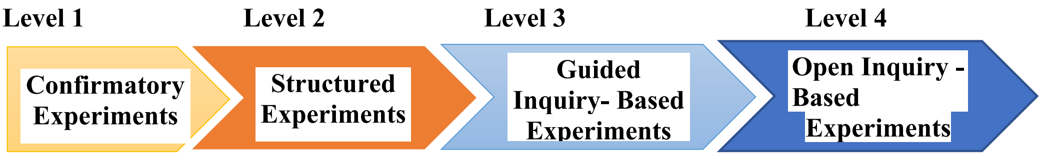

Figure 1. *Continuum of inquiry-based experiments*

The confirmatory and structured experiments represent lower inquiry levels where the teacher structures both the problem and procedures of carrying out the experiment so that students confirm a learned concept, theory, principle or scientific law after the content has been taught (Baloyi, 2017; Ural, 2016). These forms of experiments are neither true inquiry nor an effective way of developing practical skills and scientific inquiry among students (Fitzgerald et al., 2019). Thus, both confirmatory and structured experiments are regarded as TBEs. The third level of inquiry is GIBE, in which students actively engage in authentic learning activities to accomplish the assigned tasks under their teacher's guidance (Baloyi, 2017). The fourth level is an open inquiry-based experiment which represents the highest level of inquiry, where students formulate their own questions and design their own experimental methods to address the problem. Open inquiry-based experiments are very difficult to translate into teaching activities because they are highly unstructured, making it difficult for students to formulate their own problems and experimental procedures (Kinyota, 2020; Baloyi, 2017; Ural, 2016). Research shows that secondary school students can learn Physics better through GIBE than through traditional or other forms of experiments (Chatterjee et al., 2009).

Traditional-based experiments

TBEs are a form of laboratory work introduced in a step-by-step manner for students to complete the experimental task given in the worksheet (Wieman, 2015). In TBE, students are required to follow the prescribed step-by-step instructions to accomplish the assigned practical task (Chung et al., 2010). The main focus of TBEs is to teach students how to use equipment and take measurements to verify known theories, principles, facts or concepts. As a result, students can miss the potential opportunity to experience the nonlinear and complex nature of science (Kalender et al., 2021). In TBE students are told what to find, acquainted with the procedures, record their readings in tables, given the formulas needed, and are even aware of the expected answers or conclusions (Gangoli & Gurumurthy, 2007). As a result, TBE may lead to students memorizing facts and procedures instead of making a connection between the experiment and the underlying scientific concepts or ideas (Abrahams & Millar, 2008).

Guided inquiry-based experiments (GIBEs)

In GIBEs, students are provided with fewer directions but they are assigned more responsibilities to determine procedural strategies, which encourages them to make more use of practical skills (Shi et al., 2020). In GIBE, the teachers provide students with guidance in the form of leading questions to actively engage them in determining the concept through experimental inquiry activities (Maknun, 2020). One advantage of GIBE is that the leading questions are less likely to lead to frustration and anxiety among students when conducting experiments (Furtak et al., 2012). Moreover, in the GIBE approach students have a chance to ask questions, develop hypotheses, decide on the experiment design in groups, and organize roles in their experiment groups (Aydın, 2016). These GIBE practical activities can enhance students' acquisition of practical skills, hence improving their learning and achievement in Physics.

Practical skills in Physics

Process skills, inquiry skills, manipulative skills, and procedural understanding are the key practical skills that Physics students in secondary schools are expected to acquire (Liew et al., 2019; Hastuti et al., 2018; National Research Council, 2012; Akinbobola & Afolabi, 2010). These important practical skills are grouped into four domains as per the Hypothetical-Deductive Model, namely design, execution, analysis and evaluation (Liew et al., 2019). The domain of design includes practical skills such as identifying variables, choosing suitable apparatuses and designing an experimental set-up. Skills that fall under the domain of execution include setting up the apparatus, checking and using instruments with correct techniques, manipulating variables and recording data. Moreover, the domain of analysis encompasses skills related to data handling, which include performing correct calculations, analysing data to identify relationships, and making suitable deductions. The domain of evaluation encompasses skills related to students' ability to evaluate experimental results and make judgement, which include drawing conclusions judging the accuracy of results, identifying sources of errors and weaknesses, and suggesting methods to improve the experimental results (Liew et al., 2019, p. 5).

Acquisition of practical skills in Physics

The active learning activities in GIBE help students to develop their cognitive processes and practical skills in Physics unlike the step-by-step learning activities in TBE which do not allow students to further explore the experiments (Chung et al., 2010). For example, one study conducted in Indonesia revealed that Junior high school students taught through experiments done by using a guided inquiry-based approach had higher learning achievement in practical skills compared to the students who were in the control class where they were taught by using the scientific approach (Hastuti et al., 2018). Similarly, the experiment-based guided inquiry learning (EBGIL) approach was found to be superior to the experimental-based problem learning (EBPL) approach in enhancing students' acquisition of practical skills (Halim et al., 2021). These findings imply that laboratory activities in the form of the GIBE approach can be superior to other direct approaches such as the TBE approach in supporting the development of practical skills among students.

Even though some empirical studies acknowledge GIBE as a promising learning approach that can enhance students' acquisition of practical skills in Physics, there is still little evidence in the literature on its efficacy in O-level secondary schools in Tanzania. A study by Kinyota (2020) examined the extent to which inquiry-based science teaching and the nature of science are featured in secondary school curriculum documents for science subjects. Another study by Mkimbili et al. (2017) investigated the extent to which science teachers practice inquiry-based science teaching. Yet, little is known about how GIBE can enhance students' acquisition of practical skills to improve their learning achievement in Physics in Ordinary level secondary schools in Tanzania. These concerns call for the need to investigate the effect of GIBE on students' acquisition of Physics practical skills in the selected Ordinary level secondary schools in Tanzania.

Research question

To what extent do the guided inquiry-based experiments enhance students' acquisition of Physics practical skills in Ordinary level secondary schools?

Null hypotheses

The study tested four null hypotheses at a significant level of $p < .05$, which are as follows:

H_{01}: There is no significant effect of guided inquiry-based experiments on enhancing students' ability to design experiments in Physics.

H_{02}: There is no significant effect of guided inquiry-based experiments on developing students' ability to perform experiments in Physics.

H_{03}: The guided inquiry-based experiments have no significant effect in enhancing students' ability to analyse data in Physics experiments.

H_{04}: The guided inquiry-based experiments have no significant effect on developing students' ability to evaluate experimental results in Physics.

Theoretical Framework

The study was guided by constructivist learning theory based on the ideas of John Dewey. Dewey's constructivism holds the idea that in science learning comes out of authentic laboratory experiences such as observing phenomena, investigating and solving problems (Fan, 2015). The theory implies that the teaching and learning process should provide learners with an opportunity to explore their environments. The constructivist theory calls for the kind of learning that is hands-on, minds-on and authentic. The GIBE approach is situated within constructivist learning theory in which the learner is a creator of understanding under the guidance of the teacher as a facilitator. With Dewey's constructivist theory, the teaching and learning process need to be designed in a way that provokes anticipation with evocative materials enabling students to unravel a mystery rather than follow a recipe (Herman & Pinard, 2015). Therefore, with Dewey's constructivism, teachers should play multiple roles such as a facilitator during GIBE laboratory practical sessions to help students acquire practical skills essential for effective Physics learning.

Methodology

Research approach and design

The study employed a quantitative research approach to investigate the effect of GIBE on enhancing students' acquisition of Physics practical skills in the two selected Ordinary level secondary schools from Iringa and Morogoro regions in Tanzania. The quantitative research method enables the researcher to investigate research problems that call for the identification of factors that influence an outcome, the utility of an intervention or understanding the best predictors of outcomes (Cresswell & Cresswell, 2018). Therefore, with the quantitative research approach, we were able to collect quantifiable data from participants who participated in the intervention to attain accurate results needed to understand the effect of GIBE on students' acquisition of Physics practical skills. The study applied a non-equivalent quasi-experimental research design with pre-test and post-test comparison groups to minimize interruptions of students' normal learning settings in the selected schools during the intervention. Students from one demonstration secondary school in the Iringa region participated as an experimental group, and others from another demonstration secondary school in the Morogoro region participated as the control group. The characteristics of students in both schools in terms of prior practical skills and learning environments in terms of availability of Physics teachers and laboratory equipment of their schools were relatively the same.

Participants

A total of 82 Form Three students from two demonstration secondary schools in Iringa and Morogoro participated in the study. These students were taking Physics as a major subject. 49 students from the selected demonstration secondary school in the Iringa region were assigned to the experimental group and the other 33 students from the demonstration school in the Morogoro region to the control group. Among the students in the sample, male students comprised 52.4% while female students comprised 47.6% of the sample size. The two-demonstration secondary schools were purposefully selected to access Form Three students, who had similar characteristics in terms of learning environment and prior skills in doing Physics practical activities**.**

Instruments

The study applied laboratory worksheets, Physics practical tests and a practical skills observation rubric to collect the data needed to test the null hypotheses. We designed and used the laboratory worksheets to teach Physics practical activities in the form of GIBE for the students in the experimental school. We adopted a 4-D model proposed by Thiagarajan et al. (1974) to guide the process of developing and implementing the laboratory worksheets in the form of GIBE. The 4-D model provided us with coherent procedural specifications and guidelines in four key stages: define, design, develop and disseminate required for developing the laboratory worksheets. In the define stage, we set and defined learning prerequisites, including competencies and concepts. In the design process, we transformed the experiments in the form of TBE from Ordinary level Physics practical manuals in the topics of Light and Current Electricity specified by NECTA (2021) into GIBE format. The learning activities in GIBE were sequenced in five phases of implementation, which are orientation, conceptualization, investigation, conclusion and discussion based on the guidelines of the Inquiry Learning Model established by Pedaste et al. (2015).

In the develop stage, we tested the validity and practicality of the designed lab worksheets. We consulted nine experts in the area of science teaching to validate the lab worksheets in terms of content, relevance, language and graphics, whereby, the computed Aiken's score (V) was 0.81. According to the interpretation guideline by Cahyati and Yohandri (2020), this value was greater than the minimum acceptable value of 0.60 ($V > 0.60$), which means that the designed lab worksheets were valid.

On the other hand, the lab worksheets were piloted to Form Three students (*n* = 12) studying Physics in one of the demonstration schools in the Dar es Salaam region. Thereafter, the lab worksheets were rated by two Physics teachers and the 12 Form three students participated in the pilot study to test their practicality in terms of attractiveness, ease of use, time efficiency, graphics and usefulness. The computed average percentage value was 84.95. According to the interpreting guideline by Ananda and Usmeldi (2023), the computed average percentage value was greater than the minimum acceptable value of 61% indicating that the developed laboratory worksheets in the form of GIBE were practical.

We prepared a Physics practical test to assess students' practical skills in both the experimental school and the control school before and after intervention. The practical test comprised two practical questions: one from the topic of Light and another from the topic of Current Electricity, adapted from the standardised practical questions administered by the NECTA in the years 2014 and 2022 (Figure 2). Also, we adopted the practical observation rubric developed by Liew et al. (2019) to score the practical skills demonstrated by students while performing the Physics practical test. The scoring rubric was used to assess students' practical skills in the four domains: the domain of design, the domain of execution, the domain of analysis and the domain of evaluation (Appendix I). We calculated the content validity index (CVI) of the adapted practical skills observation rubric from the nine (*n* = 9) experts' ratings and its inter-rater reliability/Kappa coefficient (*K*) for raters in the experimental school and the control school from the raters' scores. The calculated value of CVI was 0.94, greater than the threshold value of 0.74 suggested by Lawshe in Shultz et al. (2014), which implies high validity of the items of the practical skills observation rubric (Liew et al., 2019). In the experimental school (Rater 1 &2), the value of the Kappa coefficient (*K*) was 0.77 while in the control school (Rater 3 & 4) it was 0.74. The computed values of Kappa coefficients (*K*) exceeded a minimum acceptable value of 0.70 ($K>.70$), implying strong agreement between the raters in both the experimental school and the control school.

2. Find a dry cell, resistance box, switch, an ammeter and a set of connecting wires in the laboratory

Then proceed as follows:

(a) Connect the selected electrical components in series, switch must be open. Draw and label clearly your circuit.

(b) Set resistance R= 1Ω, then close the switch. Read and record the ammeter reading, open the switch immediately after taking the readings.

(c) Repeat procedure 2 (b), setting the value of R= 2Ω, 3Ω, 4Ω and 5Ω.

Questions

(i) Tabulate your results including the values of 1/I.

(ii) Plot a graph of R against 1/I.

(iii) From the graph determine the slope and the vertical intercept.

(iv) Use the results obtained in 2 (iii) to determine the internal resistance and e.m.f of the selected dry cell.

(v) State two sources of errors and suggest two precautions to avoid the stated errors in this experiment.

(vi) What is the aim of doing this experiment?

Figure 2: *Sample of practical questions in Physics practical test.*

The implementation of an intervention

In the disseminate stage of the 4-D model, we distributed laboratory worksheets to regular Physics teachers for intervention in the experimental school. Before the intervention, we deliberated on students' informed consent where the selected Form Three students were informed about the study's purpose and the nature of intervention activities and that, their participation was voluntary and they could withdraw from the study at any time. Then they were invited to participate in the study. We assessed the students' prior practical skills in Physics in both the experimental school and the control school. Thereafter, we conducted a two-day training seminar for two regular Physics teachers in the experimental school on how to teach the selected topics using the developed laboratory worksheets with experiments in the form of GIBE. The trained teachers prepared lesson plans with learning activities sequenced in five phases: orientation, conceptualization, investigation, conclusion and discussion (Appendix II) based on the Inquiry-Based Learning Model by Pedaste et al. (2015) for teaching Physics laboratory work in the form of the GIBE.

The intervention began with the orientation phase, in which the teacher and students collaboratively decided the aim of the experiment. In the conceptualization phase, the students asked questions and formulated a problem and hypotheses. In the investigation phase, the students planned the exploration, conducted experiments, and collected and analyzed data to generate answers and explanations to the stated problem/question. Finally, in the discussion phase, the students were encouraged to present and communicate the results of their experiments to others, reflect, evaluate the experimental results, and state how they would apply the generated knowledge in their daily lives. The trained teachers prepared, developed and then taught a total of 10 lessons, each of which took 80 minutes. The intervention was done for six weeks, followed by post-testing.

Contrarily, we consulted two Physics teachers in the control school to teach the same topics to Form Three students by using the TBE approach. No training was offered to these Physics teachers. The teachers planned and taught the lessons using the common lesson plans designed by the MoEVT. The lesson development template had five stages, namely introduction, new knowledge, reinforcement, reflection and consolidation (Appendix III). Like the teachers of the experimental school, these teachers prepared and taught the same number of lessons in 80 minutes by using the laboratory worksheets with exemplary experiments in the form of TBE adopted from NECTA (2021) for six weeks followed by post-testing.

Data collection procedures

The data were collected using adopted practical skills observation rubrics. To achieve data collection with minimal researchers' biases, we conducted a one-day training seminar for four Physics tutors from the Teachers' Colleges in the respective Iringa and Morogoro regions on how to rate students' practical skills using the adopted practical skills observation rubrics. Two Physics tutors from one of the Teachers' College in Iringa region administrating the experimental school as its demonstration school were trained to rate students' practical skills in the experimental school. The other two Physics tutors from Teachers' College in Morogoro region administrating the control school as its demonstration school, received the same training to rate students' practical skills in the control school. The trained tutors used the practical skills observation rubrics to score students' practical skills demonstrated when conducting experiments in Physics practical tests before and after intervention. The study used the same data collection instruments with the same items under the same conditions in pre-testing and post-testing in the experimental and the control school to control instrumentation and selection threats to the validity of research findings.

Data analysis procedures

Descriptive and inferential statistical techniques were used to analyze data collected through practical skills observation rubrics. The descriptive statistics were used to report data analysis in the pre-test and post-test results in terms of normalised gain (<*g*>), means and standard deviations. The normalised gain (<g>) scores were interpreted based on the guideline by Hake (1998), whereby (<g>) ≥ 0.70 = high, 0.70 > (<g>) ≥ 0.30 = moderate and (<g>) < 0.30 = low. In inferential statistics, we performed paired and independent sample t-tests and reported effect size (*Cohen's d*) with the aid of SPSS version 25. The paired sample t-test was performed to understand the effectiveness of GIBE and TBE in the respective experimental and control groups. The independent sample t-test was conducted to assess the differences in post-test mean scores for the acquisition of practical skills between students in the experimental school and control school. The inferential statistics tests were performed at a level of significance of $p < .05$. The values of effect sizes were interpreted based on the guideline proposed by Cohen (1988, p. 22) where Cohen's $d = .20$ (small effect), $d = .50$ (medium effect) and $d = .80$ and above (large effect).

Results and Discussion

Pre-testing results

An independent sample *t*-test was conducted to assess students' prior practical skills in Physics in the experimental school and control school before the intervention, at a level of significance of $p < .05$. The results show that there was no significant difference in the mean scores between students in the experimental school ($M = 16.20$, $SD = 8.68$) and those the control school ($M = 18.55$, $SD = 4.94$), $t(80) = -1.55$, $p = .125$, (two-tailed). Similarly, the series of independent sample *t*-tests that were performed for each domain of practical skills (domain of design, execution, analysis and evaluation) showed no significant difference in the mean scores between the experimental school and the control school. Table 1 presents the inferential statistical results for pre-testing.

Table 1

Pre-test Independent Samples T-tests of Students' Mean Practical skills Scores

Domain	**Experimental School**		**Control School**				
	M	*SD*	*M*	*SD*	*(df)*	*t*	*p*
Design	4.08	2.67	3.91	1.86	80	0.32	.748
Execution	7.69	4.40	9.30	2.83	80	-1.86	.067
Analysis	2.06	1.78	2.61	1.48	80	-1.46	.149
Evaluation	2.37	2.35	2.73	1.99	80	-0.72	.472
Total Mean Scores	16.20	8.68	18.55	4.94	80	-1.55	.125

Key: *M* = Mean, *SD* = Standard

The results presented in Table 1 indicate that the pre-test mean scores were higher in the control school than in the experimental school for the domain of execution, analysis and evaluation. However, the inferential statistical results show that there were no significant differences in mean scores in the experimental school and the control school. These results suggest that the student's prior practical skills in both schools in all four domains were considered equal before intervention. Hence, we implemented the intervention in these schools with confidence that no automatic bias would occur due to students' differences in prior practical skills.

Domain of design

The domain of design involved the assessment of four practical skills which were related to students' ability to design an experiment. These practical skills included students' ability to identify variables correctly, design functional experimental set-ups, determine suitable ranges for manipulated variables and ability to select suitable intervals for values of manipulated variables. The mean scores and normalised gain (<g>) were computed to assess gain in the mean scores in the domains of design after implementation of GIBE in the experimental school, and TBE in the control school. Figure 3 presents the normalised gain scores.

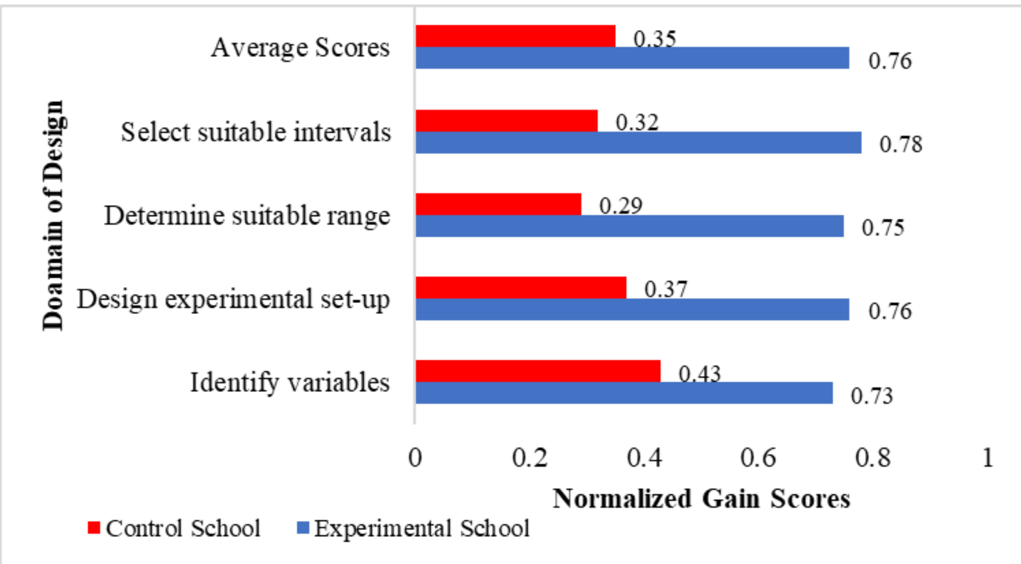

Figure 3: *Normalised gain scores in the experimental school and the control school for domain of design*

The results in Figure 3 show that, the normalised gain *(<g>)* score in the experimental school was highest in developing students' ability to select suitable intervals, followed by the ability to design a functional experimental set-up, determine a suitable range and identify variables correctly. In the control school, students' ability to identify variables correctly had moderate scores followed by the ability to design functional experimental set-up and select suitable intervals. Students in the control school had low normalised gain scores for the ability to determine a suitable range. A paired sample *t*-test was performed to find out if a change in students' mean scores for the acquisition of practical skills in the domain of design from pre-test to post-test in the experimental school and the control school was significant. Table 2 presents the results.

Table 2

Paired Sample T-Test Results for the Domain of Design in The Experimental and the Control School

Schools	**Pre-test**			**Post-test**									
	N	*M*	*SD*	*N*	*M*	*SD*	*(df)*	*t*	*p*	*d*	*MD*	*Lower*	*Upper*
Experimental	49	4.07	2.67	46	10.07	2.73	45	-10.99	.000	3.29	-6.02	-7.12	-4.92
Control	33	3.91	1.86	33	6.76	1.79	32	-7.93	.000	2.79	-2.83	-3.58	-2.12

Key: *p* = Significant level, *t* = t-value, d = Cohen's d and *MD* = Mean difference.

The results in Table 2 indicate that there was a statistically significant increase in mean scores from the pre-test to the post-test in both the experimental school and the control school. GIBE and TBE resulted in a large effect size with Cohen's d values of 3.29 and 2.79 respectively. The independent sample *t*-test was performed to test if the difference in post-test mean scores between the experimental and the control school was statistically significant. Table 3 presents the results.

Table 3

Independent Sample T-test Results for the Domain of Design in the Experimental and the Control School

Experimental School			**Control School**									
N	*M*	*SD*	*N*	*M*	*SD*	*(df)*	*t*	*p*	*d*	*MD*	*Lower*	*Upper*
46	10.07	2.73	33	6.76	1.79	77	6.09	.000	2.67	3.31	2.23	4.39

The results in Table 4 indicate a statistically significant difference in mean scores for students' acquisition of practical skills in the domain of design between the experimental school and the control school. GIBE had a large effect size with Cohen's d value of 2.67. The significant level was 0.000 ($p < .05$), rejecting the first null hypothesis (H_{01}) that, there is no significant effect of guided inquiry-based experiments on enhancing students' ability to design experiments in Physics.

The independent t-test results affirmed that there was a significant difference with a large effect size in the acquisition of practical skills in the domain of design between students in the experimental school and the control school. In the GIBE classroom, the students discussed and agreed on the nature of independent and dependent variables, designed functional experimental set-ups, and determined suitable ranges and intervals of manipulated variables. The practical activities in the investigation of GIBE might have played a fundamental role in enhancing the development of practical skills related to student's ability to design experiments in physics in the experimental school. Unlike the practical activities in TBE where students were required just to follow the prescribed step-by-step procedures while performing the assigned practical tasks.

Similar claims were reported by Juniar et al. (2020) that the use of a guided inquiry model resulted in substantial development of students' ability to design experiments in Chemistry. However, the findings in this study contrast with those by Blumer and Beck (2019) that, the use of laboratory courses with guided inquiry modules did not improve students' scientific reasoning skills and experimental design skills from pre-test to post-test. This is attributed to the fact that, in GIBE practical activities students tend to experience some difficulties in designing reliable experiments to solve the assigned practical tasks. The findings by Sujarittham et al. (2019) revealed that, the use of guided-inquiry laboratory worksheets enhanced only students' ability to identify experimental variables of an investigation because students spent much time designing the experiment by working on answering the guided-inquiry questions and doing the experiments.

Domain of execution

In the domain of execution, eight practical skills related to students' ability to perform an experiment were assessed. They included students' ability to choose suitable apparatus for measurement, check the functionality of instruments, set up functional apparatus, and test-run the experimental set-up. Other skills were the ability to use measuring instruments with the correct techniques, take precautions to improve the accuracy of data collected, record all measurements and ensure safety in the laboratory. The normalised gain (<*g*>) was calculated to assess the gain in the mean scores after GIBE intervention in the experimental school, and TBE in the control school. Figure 4 presents the normalised gain scores.

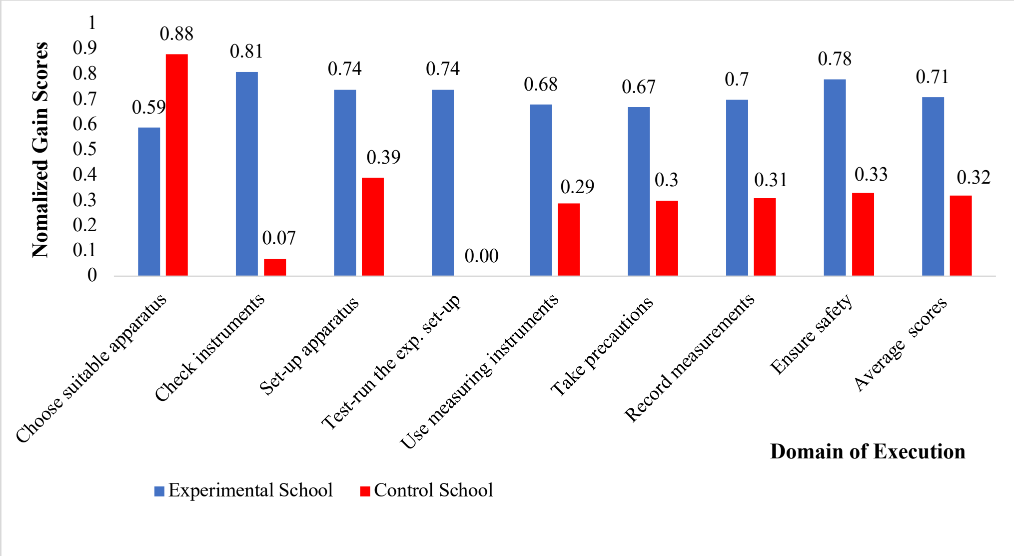

Figure 4: *Normalised gain scores in the experimental school and control school domain of execution*

The results in Figure 4 indicate that students in the experimental school had higher normalised gain *(<g>)* scores than those in the control school for all the assessed practical skills except the ability to choose suitable apparatus. In the control school, the student's ability to test run the experimental set-up had no mean gain. A paired sample *t*-test was performed in both the experimental school and the control school to test if the changes from pre-test to post-test were statistically significant. The results are presented in Table 4.

Table 4

Paired Sample T-test Results for the Domain of Execution in the Experimental and the Control School

Schools	Pre-test			Post-test									
	N	*M*	*SD*	*N*	*M*	*SD*	*(df)*	*t*	*p*	*d*	*MD*	*Lower*	*Upper*
Experimental	49	7.69	4.40	46	19.48	3.75	45	-14.86	.000	4.42	-11.93	-13.55	-10.32
Control	33	9.30	2.83	33	12.85	2.72	32	-5.35	.000	1.88	-3.55	-4.90	-2.19

The results in Table 4 show that, there was a statistically significant increase in mean scores from the pre-test to post-test in the experimental school and the control school. The effect sizes of GIBE and TBE were large with Cohen's d values of 4.42 and 1.88, respectively. The independent sample *t*-test was conducted to test if the difference in post-test mean scores between the experimental school and the control school was statistically significant. Table 5 presents the results.

Table 5

Independent Sample T-test Results for the Domain of Execution in Experimental and Control School

Experimental School			**Control School**									
N	*M*	*SD*	*N*	*M*	*SD*	*(df)*	*t*	*p*	*d*	*MD*	*Lower*	*Upper*
46	19.48	3.75	33	12.85	2.72	77	8.65	.000	1.96	6.63	5.10	8.16

The results in Table 5 indicated a statistically significant difference in the mean scores for students between the experimental school and the control school. The GIBE had a large effect size with Cohen's d statistic value of 1.96. The significant level was 0.000 (p <.05), rejecting the second null hypothesis (H_{02}) that, there is no significant effect of guided inquiry-based experiments on developing students' ability to perform experiments in Physics.

The findings revealed that students in the experimental school scored higher normalised gain *(<g>)* scores than those in the control school in seven assessed practical skills except the ability to choose suitable apparatus. This observation might be attributed to the nature of practical activities in TBE where students in the control school were directly given the required apparatus unlike in the GIBE approach where students had to select the relevant apparatus themselves. Moreover, the use of the GIBE approach attributed to significantly higher mean scores in the experimental school as compared to those in the control school in enhancing the development of practical skills related to students' ability to perform experiments. This implies that the GIBE practical activities in the investigation phase enabled students to develop the ability to choose, check and use measuring instruments, and do observation to collect the data needed to explain the concepts under investigation. This observation concurs with Hastuti et al. (2018) that, the procedural and manipulative skills which focus on tool operation develop well when students are given an opportunity to practice directly through laboratory experiments under the GIBE approach. Similarly, the use of the guided–inquiry laboratory experiments model in teaching was found to be effective in improving the quality of students' ability to carry out experiments in Chemistry courses (Wahyuni & Analita, 2017). Students are better at using equipment and carrying out practical procedures if they get opportunities to practice how to operate them rather than just being shown how they operate (Millar, 2010).

Domain of analysis

In the domain of analysis, the study assessed three practical skills that covered student's ability in data handling. These included: students' ability to perform correct calculations, analyse data to obtain results/relationships and state the correct relationship/make correct deductions. The normalised gain scores are presented in Figure 5.

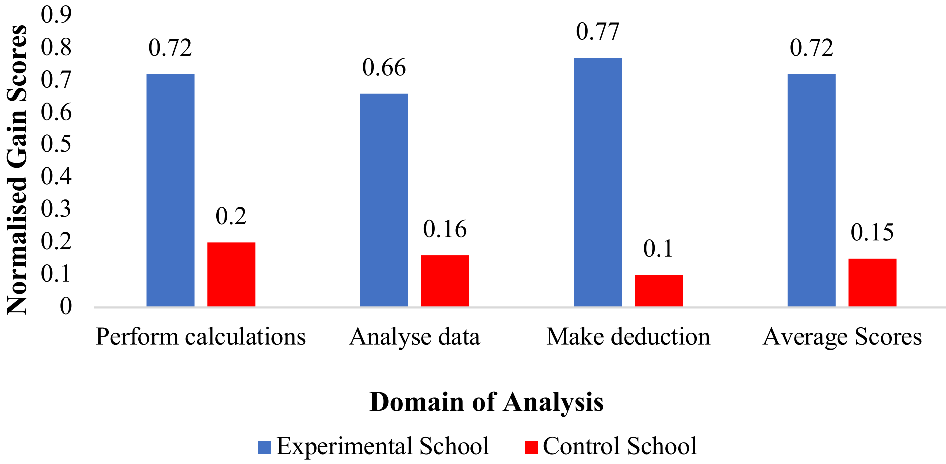

Figure 5: *Normalised gain scores in the experimental school and control school domain of analysis*

The results in Figure 5 indicate that students engaged in GIBE practical activities in the experimental school outperformed those in the control school who learned through the TBE approach. The use of GIBE in the experimental school resulted in the highest normalised gain score for students' ability to make deductions followed by the ability to perform calculations and moderate normalised gain score for ability to analyse data. In the control school, the students scored low normalised gain for the ability to perform calculations, analyse data and the ability to make deductions. A paired sample *t*-test was conducted to test if the changes from pre-test to post-test were statistically significant. Table 6 presents the results.

Table 6

Paired Sample T-test Results for the Domain of Analysis in the Experimental and the Control School

Schools	**Pre-test**			**Post-test**							
	N	*M*	*SD*	*N*	*M*	*SD*	*t*	*d*	*MD*	*Lower*	*Upper*
Experimental	49	2.06	1.78	46	7.09	1.93	-14.10	4.27	-5.20	-5.94	-4.45
Control	33	2.61	1.48	33	4.00	1.84	-3.61	1.88	-1.39	-2.18	-0.61

The results in Table 6 indicate that there was a significant increase in mean scores from the pre-test to the post-test with a p-value less than .05 ($p < .05$). The effect size of GIBE and TBE was large with Cohen's d statistic value of 4.27 and 1.88 respectively. The independent sample *t*-test was conducted to test if the difference in post-test mean scores between the experimental and the control school was significant. Table 7 presents the results.

Table 7

Independent Sample T-test Results for the Domain of Analysis in the Experimental and Control School

Experimental School			**Control School**									
N	*M*	*SD*	*N*	*M*	*SD*	*(df)*	*t*	*p*	*d*	*MD*	*Lower*	*Upper*
46	7.09	1.93	33	4.00	1.84	77	7.15	.000	1.63	3.09	2.23	3.95

The results in Table 7 show that there was a statistically significant difference in the mean scores for students between the experimental school and the control school. The effect size of GIBE was large with Cohen's d value of 1.63. The significant level was 0.000 ($p < .05$). These results reject the third null hypothesis (H_{03}) that the guided inquiry-based experiments have no significant effect on enhancing students' ability to analyse data in Physics experiments.

The results showed that students who were taught by using the GIBE approach in the experimental school scored higher in performing correct calculations, analysing data and stating deductions than those who learned through the TBE approach in the control group. The independent sample t-test results affirmed that the use of the GIBE approach was superior to TBE in enhancing the development of students' analytical skills. The guided-inquiry practical activities in the investigation phase of GIBE implementation might have played a vital role in contributing to the observed improvement in students' ability to perform data analysis. In this phase, students performed calculations, analysed data, organized data in tables and drew graphs, sketches and diagrams to gain information needed to state the relationships and make inferences from the experimental results. These findings in this study, align with that by Febri et al. (2020) whereby the high stake of analysis competence among the students was probably due to the use of the GIBE lab model. Similarly, Wahyuni and Analita's (2017) findings reported that the implementation of guided-inquiry laboratory experiments substantially improved students' ability to perform data analysis. After collecting data, students must organise the data into tables, diagrams and graphs to present the data in a way that supports the conclusions and accuracy of the results.

Domain of evaluation

In the domain of evaluation, the study assessed five practical skills related to students' ability to evaluate experimental results. These were students' ability to conclude the findings of the experiment, make a judgement on the accuracy of the results, suggest a suitable title and aim of the experiment, state the sources of errors and provide suggestions to improve experimental design. Figure 6 presents the normalised gain scores.

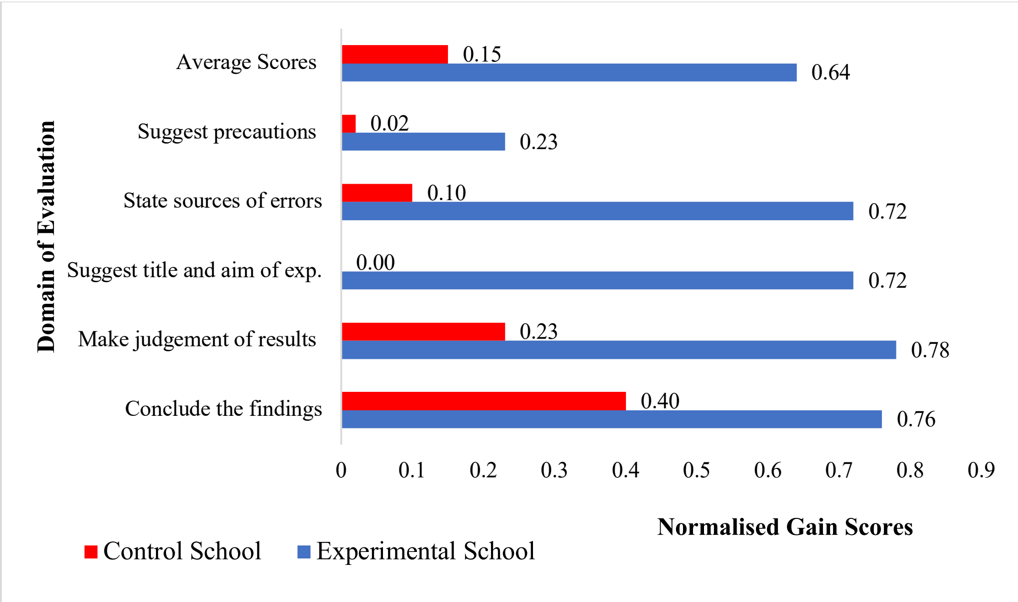

Figure 6: *Normalised gain scores in the experimental school and the control school domain of evaluation*

The results in Figure 6 indicate that the normalised gain scores were higher in the experimental school than in the control school. In the experimental school, the normalised gain score was highest for students' ability to make judgements of results followed by concluding findings, stating sources of errors and suggesting the title and aim of the experiment. While students' ability to suggest precautions scored a low normalised gain. In the control school, the students scored moderate normalised gain for the ability to conclude findings followed by low normalised gain scores for the ability to make the judgement of results, state sources of errors, and suggest precaution and zero gain for the ability to suggest suitable title and aim of the experiment. A paired sample *t*-test was performed to test if the changes from pre-test to post-test were statistically significant. The results are presented in Table 8.

Table 8

Paired Sample T-test Results for the Domain of Evaluation in Experimental and the Control School

Schools	Pre-test			Post-test							
	N	*M*	*SD*	*N*	*M*	*SD*	*t*	*d*	*MD*	*Lower*	*Upper*
Experimental	49	2.37	2.35	46	11.70	3.13	-16.61	4.96	-9.37	-10.51	-8.23
Control	33	2.73	1.99	33	4.06	2.87	-2.31	.81	-1.33	-2.51	-0.16

The results in Table 8 show a statistically significant increase in mean scores from pre-test to post-test in both the experimental school and the control school. The effect size of GIBE and TBE was large with Cohen's d values of 4.96 and .81 respectively. The independent sample *t*-test was performed to test if the difference in post-test mean scores between the experimental and the control school was significant. Table 9 presents the results.

Table 10

Independent Sample T-test Results for the Domain of Evaluation in Experimental and Control School

Experimental School			Control School									
N	*M*	*SD*	*N*	*M*	*SD*	*(df)*	*t*	*p*	*d*	*MD*	*Lower*	*Upper*
46	11.70	3.13	33	4.06	2.87	77	11.06	.000	2.50	7.64	6.26	9.01

The results in Table 9 show that, there was a statistically significant difference in the mean scores for students in the experimental school and the control school. The effect size of GIBE was large with Cohen's d value of 2.50. The value of the significant level *(p)* was 0.000 ($p < .05$) rejecting the fourth null hypothesis (H_{04}) which proposed that the guided inquiry-based experiments have no significant effect on developing students' ability to evaluate experimental results in Physics.

The results showed that students in the experimental school taught using GIBE had significantly higher mean scores than in the control school taught using TBE in the ability to conclude findings, make judgements about the experimental results, and suggest the title and aim of experiments, and the ability to state possible sources of errors in the experiment. The learning activities in the conclusion and discussion stages of GIBE implementation that encouraged students to connect explanations to scientific knowledge, and evaluate and communicate results are likely to play a vital role in enhancing students' abilities to evaluate results in the domain of evaluation. Similar claims were reported by Prihmardoyo et al. (2017) that guided inquiry laboratory-based biology modules are effective in supporting the development of student's ability to formulate experimental objectives and draw conclusions. However, the findings on the aspect of students' ability to conclude findings contradict those of Wahyuni and Analita (2017), which showed that the use of guide inquiry laboratory experiments to improve students' analytical thinking skills in chemistry resulted in low improvement in formulating conclusions. In this study, even though GIBE led to higher improvement in the four aspects of practical skills as compared to TBE, the analysis of normalised gain indicated low improvement in students' ability to explain precautions for reducing errors in the experimental design in the domain of evaluation. Students might have experienced difficulties in anticipating possible precautions to reduce errors in the experimental design.

Conclusions and Recommendations

From the study's findings, several conclusions can be drawn. While both approaches offer value in learning Physics through practical activities, the use of GIBE leads to significant gains in acquiring practical skills. Specifically, it enhances students' ability to design experiments (H01), perform experiments (H02), analyse data (H03), and evaluate experimental results (H04). In contrast, the traditional approach primarily promotes memorisation and repetition of procedures, with limited impact on the development of practical skills in Physics.

The study applied a quasi-experimental design with restricted full randomisation of participants and similar methods to assess students' acquisition of practical skills in pre-testing and post-testing during intervention. Thus, long intervals between pre-testing and post-testing could have minimized the effect. The study recommends that other pure experimental studies be conducted on other topics in physics to establish a strong generalizable finding for full adoption of GIBE in teaching and learning of Physics. In addition, the Physics teachers should be more creative and innovative in planning collaborative laboratory practical activities in the form of GIBE to foster students' acquisition of practical skills essential for effective learning of Physics. Moreover, the school administration in collaboration government should create a well-equipped Physics laboratory to support teaching and learning through GIBE practical activities.

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Opportunities to Integrate Inquiry-Based Learning in Chemistry Subject: Evidence from Secondary Schools in Tanzania

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Abstract

Inquiry-based learning (IBL) has been adopted globally as a student-centred approach to engage students in critical and innovative thinking. Creating an environment with opportunities for IBL has received little attention due to school contextual challenges. This study explored opportunities for integrating IBL into Chemistry subject. A qualitative research approach and a single case study design were employed. A sample of six teachers and thirty-two students was purposively selected. Data was collected through interviews, Focus Group Discussions (FGDs), classroom observations, and documentary review and analysed thematically. Findings revealed that opportunities for implementing IBL include performing practical activities, conducting discussions and presentations, and questioning and answers. This study recommends continued integration of inquiry activities in learning to cultivate the development of critical thinking skills.

Keywords: *inquiry-based learning, scientific literacy, competencies, critical thinking, problem solving*

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Introduction

The call for improved student learning in secondary schools has become a global agenda in preparing students with relevant knowledge, skills and positive attitudes towards personal and national development (Crawford, 2014; Molinero & Belart, 2022; Wheatley, 2018). The process of improving learning is geared toward supporting students to think critically, make informed decisions and solve real-life challenges (Chowdhury, 2018). In developing countries and Tanzania in particular, science education is aimed at helping students acquire scientific knowledge and a broad range of 21st-century skills (Crawford, 2014; Kasuga et al., 2022; Mkimbili, 2022). The skills emphasised include critical thinking, communication, collaboration and creativity (Chu et al., 2017; Tindangen, 2018). For supporting students' mastery of competencies, IBL is considered a powerful strategy to foster students' acquisition of relevant knowledge, skills, and positive attitudes (Chowdhury, 2018; Crawford, 2014; Kibga et al., 2021). The IBL strategy has the potential to transform how students learn by facilitating increased engagement, active learning, and increased responsibility for their own learning (Wheatley, 2018). In this study, IBL is defined as activities that engage students in learning by asking questions, conducting scientific investigations, collecting data as evidence, interpreting, and communicating the results.

Inquiry-based learning in the context of Chemistry subject in Tanzania

Chemistry is one of the science subjects that provide knowledge and skills applicable to various occupations. This study focuses on Chemistry because it connects multiple scientific disciplines and encompasses essential knowledge and skills that graduates can apply in diverse fields, including medicine, industry, and agriculture (Buchanan, 2015). To help students develop the intended competencies in Chemistry, teachers must implement effective instructional practices that actively engage students in learning activities and foster collaboration in constructing knowledge, acquiring relevant skills, and shaping appropriate attitudes. From a social constructivist perspective, inquiry-based classroom practices enhance students' interactions with content and learning resources, facilitating the development of desired skills (Chu et al., 2017).

In Tanzania, the competence-based Chemistry syllabus emphasises the use of constructivist approaches to promote active learning and social construction of knowledge through collaborative works. For example, some of the objectives advocate students designing and performing experiments, acquiring Chemistry skills, knowledge, and principles to solve daily life problems, and appreciating application of the scientific principles and knowledge in the exploitation of natural resources with the conservation of the environment (MOEVT, 2010). In line with the stated objectives, the general expected competencies include the student's demonstrated ability to develop knowledge in Chemistry by doing various activities and experiments, applying Chemistry knowledge, skills and principles to solve daily life problems, using science and technological skills in conserving and making sustainable use of the environment (MOEVT, 2010).

To attain the desired competencies, student-centred teaching strategies have been emphasised for students to actively participate in constructing knowledge and developing the senses of an inquiry mind (MOEVT, 2010; Nzima, 2016). Studies conducted in the Tanzania context have indicated that IBL is not well practised in Tanzania due to contextual challenges (Athumani, 2019; Kinyota, 2020). Scholars also argue that IBL is practised at the lower levels of inquiry due to varied Chemistry teachers' epistemological views towards IBL, consequently, affecting its implementation (Kibga et al., 2021: Kinyota, 2020). Athumani (2019) asserted that students need to learn Chemistry in a continuum of inquiry practices with emphasis on the highest levels. In particular, some studies conducted Tanzania have found that guided inquiry is an effective strategy for enhancing the learning of science compared to unguided inquiry (Mkimbili 2022; Maro, 2013). In guided inquiry, the teacher, materials, and learning environment provide students with learning support to use procedures in conducting investigations (Kinyota, 2020).

Based on these studies, there is limited knowledge on the instructional activities' potential for implementing IBL in Chemistry classrooms in Tanzania. Since previous research indicates practices of inquiry approach at lower levels, further critical analysis of IBL instructional practices is needed to broaden understanding and practices of IBL opportunities through contextual learning activities. This study sets out to explore opportunities for integrating IBL in Chemistry classrooms in the Tanzania context. In such regard, the objective of the study was to *explore Chemistry teachers' and students' instructional strategies employed as opportunities to practice IBL.* In addressing this objective, the study answered the following research question: H*ow do Chemistry teachers' and student's instructional strategies reflect opportunities for practising IBL*? This study provides insights into the need for creating a learning environment that can support the enactment of IBL as one of the student-centred teaching approaches that maximise students' engagement and development of critical thinking and problem-solving skills.

Literature Review and Theoretical Framework

Conceptual literature review

An overview of inquiry-based learning

Inquiry-based learning (IBL) has appeared with increasing frequency for educational reforms in science education over the past century (Artigue & Blomhøj, 2013) indicating a major educational trend. We go back to the origin of inquiry as a pedagogical concept in the work of Dewey (e.g. 1916, 1938. The strategy gained its attention from scientific inquiry practices during science education reforms

(Artigue & Blomhøj, 2013; Crawford, 2014)indicating a major educational trend. We go back to the origin of inquiry as a pedagogical concept in the work of Dewey (e.g. 1916, 1938. IBL is defined by scholars in a variety of forms, contexts and disciplinary fields (Crawford, 2014). For example, Crawford (2014) defined IBL as referring to the practices of involving students in asking questions, carrying out scientific investigations, gathering data, and communicating findings to develop an understanding of the natural world.

Using IBL is encouraged since it is an effective strategy for raising students' motivation in science subjects and increasing their understanding of scientific concepts (Athumani, 2019; Chakim & Andayani, 2021). IBL can also foster students' deep thinking and application of knowledge in real-life settings (Chu et al., 2017). Similarly, the IBL strategy contributes to increasing students' problem-solving skills to become a scientific literacy citizenry capable of addressing the challenges of the 21st century (Athumani, 2019). Learning activities that offer students opportunities to investigate Chemistry phenomena through processes that involve measuring, collecting data, analysing, and evaluating enhance activity-based learning and the development of science process skills (SPS) (Kasuga et al., 2022; Maro, 2013). Activities that prompt students to think through thought-provoking questions and carry out scientific investigations beyond recipe-based information, enable students to explain Chemistry concepts and phenomena at different levels of inquiry (Ibnu & Rahayu., 2020; Tawfik et al., 2020).

The continuum of inquiry

The continuum of inquiry is a series of development stages in learning that determines the level of thinking skills students demonstrate in the acquisition of knowledge and skills (Banchi & Bell, 2008). There are four levels of inquiry through which students can gradually develop critical thinking as they engage in inquiry-oriented activities. The continuum of inquiry includes confirmation, structured, guided and open inquiries as illustrated in Figure 1.

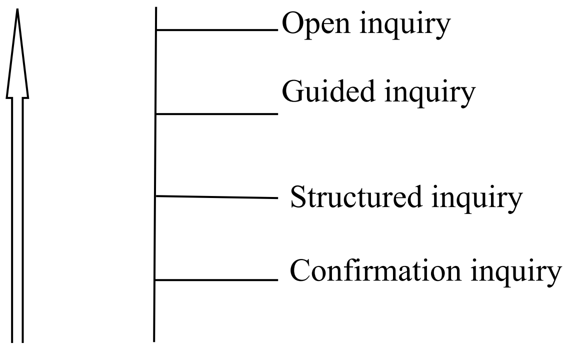

Figure 1: *The Continuum of Inquiry as Adapted from Banchi and Bell (2008)*

Figure 1 presents different levels of the continuum of inquiry learning for students that can be demonstrated as they engage in activities from the lower level of inquiry of confirmation inquiry to open inquiry. In the confirmation inquiry, students verify principles used in learning activities whose outcomes are clearly defined. In the structured inquiry, students investigate the teacher's questions by using arranged procedures. This form of inquiry is useful in supporting students understanding of SPS and acquiring procedural knowledge. For the guided inquiry, the teacher presents questions for students to investigate by using their own designed procedures (Banchi & Bell, 2008). At this level, the teacher acts as a facilitator to guide students in their investigations. In the highest level of open inquiry, students are left free to construct their own questions and procedures for carrying out the investigations (Jiang & McCosmas, 2015). As claimed by Molinero and Belart (2022), students can be engaged in inquiry activities which involve formulating problems, analysing the given procedures and executing investigations. They can further construct models, debate with each other and form coherent arguments. In this regard, instructional activities should offer students opportunities to explore information, collect and analyse data, and construct knowledge at different levels of inquiry.

Features of inquiry-based learning

The National Resource Centre [NRC] in 2007 postulated that the essential features of the IBL involve the presence of scientifically oriented questions, presentation of learning evidence in line with the scientifically oriented questions and presence of explanations developed by students from their evidence to address the scientifically oriented questions. In addition, it includes the presence of evaluation for the explanations that reflect scientific understanding and finally communicating justifications of their proposed explanations (NRC, 2007). When planning for instructional activities, features of IBL can be embedded in learning activities to support systematic investigations and students' learning through scientific inquiry.

Opportunities for inquiry-based learning in chemistry

IBL can be implemented through diverse learning opportunities that develop critical and creative thinking for students. Studies indicate that IBL can be implemented using questions that challenge students thinking, study visits, inquiry-based debates and projects (Shanmugavelu et al., 2020). Other opportunities for IBL encompass outdoor inquiry activities, laboratory practices, solving complex problems, and discovery learning (Hendratmoko et al., 2024). However, in some situations, practical activities performed by students can have little impact on promoting IBL practices due to teachers' insufficient knowledge in organising meaningful learning experiences (Kwitonda et al., 2021). A full utilisation of opportunities for IBL practices is indispensable in improving students' mastery of competencies in various learning domains.

Theoretical framework of the study

The study was underpinned by social constructivism learning theory which is a collaborative form of learning based on students' interaction, active engagement and construction of knowledge in a social setting (Mishra, 2023). The theory was proposed by Levy Vygotsky (1978) proclaiming that social construction of meaning is achieved through collaborative learning, problem-solving techniques and experimentation (Vygotsky, 1978). Therefore, students can actively and collaboratively construct knowledge in a social setting using their previous experiences (Crawford, 2014). In this perspective, interaction, collaboration, and social construction of knowledge are the key tenets of the theory (Mishra, 2023). The theory provides insights into IBL instructional practices that offer opportunities for students to construct knowledge in a collaborative learning environment.

Since the central principle of social constructivism learning theory is to make learning an active process, teachers require a deep understanding of the IBL to enable students' active participants in the process of knowledge construction (Crawford, 2014; Wheatley, 2018). The theory supports IBL to be the student-centred, more engaging and fundamentally participatory strategy. Thus, chemistry teachers need to create learning situations that can evoke students' prior knowledge as they explore learning situations. Based on social constructivism theory, the overall teaching and learning should encourage students to apply scientific processes and support them to be scientifically literate (NRC, 2007). Regarding this theory, effective use of IBL is viewed to promote collaboration, active participation, interactive learning, and self-directed learning in the construction of knowledge at different levels of inquiry.

Methodology

Research approach and design

The study employed a qualitative research approach to explore instructional practices' potential for the implementation of IBL within the participants' perspectives. Creswell and Creswell (2018) contend that the qualitative research approach provides researchers with an opportunity to explore things in their natural setting and make sense of the meaning people present. In this study, the qualitative approach enhanced capturing both teachers' and students' instructional practices potential for IBL in Chemistry. Specifically, a single case study design was employed in the study. Previous studies have utilised a qualitative case study design to conduct thorough investigations into socio-cultural practices, such as FGM in Tarime, Tanzania (Pesambili, 2013; Pesambili & Mkumbo, 2018, 2024). These studies demonstrate the effectiveness of this design in enhancing thorough exploration of the instructional practices, which deemed potential for implementing IBL. As supported by Yin (2018), using a case study allows in-depth insight and a better understanding of an issue under investigation. Therefore, the design brought a deeper insight into opportunities for IBL being explored.

Sample

The study was conducted in four secondary schools in Iringa Municipality and employed a total of 38 participants (6 Chemistry teachers and 32 Chemistry students). Chemistry teachers and students were obtained using purposive sampling to participate in the study. This sampling technique was effective to be used because it focused on selecting Chemistry teachers as key informants with knowledge and expertise. Six Chemistry teachers were included in the study to attain saturation points on teachers' perspectives of IBL practice. The study focused on teachers with adequate experience and proficiency in teaching Chemistry in Form Three classes. Similarly, purposive sampling was used to select Form Three Chemistry students who were well thought-out as motivated to continue pursuing the subject, had good experiences in learning Chemistry, and had future determination to pursue careers based on Chemistry knowledge and skills. However, Form Four Chemistry students were not selected despite their experience due to the time limit following their intense preparation for the final examinations and the pressure to make revisions for the covered chemistry content from Form One to Form Four. By using simple random purposive sampling, eight students were selected from each of the four schools to participate in the FGD because all had an interest and commitment to continue learning Chemistry subject. Therefore, purposive sampling techniques were useful in obtaining participants with characteristics desired to provide credible information.

Data collection tools

Interviews

Semi-structured interviews were conducted with Chemistry teachers to gain a deeper understanding of their perspectives on instructional practices that present opportunities for implementing IBL. An interview guide was used to focus the discussion on potential opportunities for IBL and its relevance in promoting student engagement and skill acquisition. Field notes on issues raised during the interview sessions were taken. Semi-structured interviews were conducted before classroom observation to gain teachers' insight on strategies employed for the practice of IBL. Some of the interview questions asked *how do you make students engaged in the Chemistry lesson. What activities are performed to support learning through IBL?* A total of six interviews, each lasting for approximately 40-45 minutes were conducted.

Observations

Non-participant observations were also used to obtain direct evidence of the eye and experience first-hand information. As asserted by Handley et al (2020), non-participant observation facilitates the collection of data from naturally occurring situations that can highlight disparities between reported practice and actual practice. Studies also indicate that non-participant observation methods provide researchers the opportunity to systematically capture participants' social meanings, everyday activities, and the dynamics of lesson interactions between teachers and students in the classroom (Pesambili, 2020a, 2020b). In this study, non-participant observations enabled the researcher to experience activities potential for implementation of IBL in the classroom setting. This technique also enhanced an insightful understanding of students' collaboration in exploring, investigating, and performing laboratory activities and discussions. Similarly, findings from classroom observation were used for triangulation of information gathered from Chemistry teachers through interviews regarding their practice of IBL. No potential bias was vested in the study due to researchers' beliefs on expected outcomes or participants' characteristics and their responses to questions.

Documentary reviews

A documentary guide was employed to review the Chemistry syllabus and lesson plans and examine the objectives, competencies, strategies, resources and activities carried out by students as scientific practices. The documentary guide consisted of statements that required indication for the presence/absence of specific competencies, activity-oriented plans for the teaching, use of student-centred instructional strategies, and relevant resources for engaging students in the lessons. A documentary guide enabled the collection of the data relevant to the study objective.

Focus group discussions

Focus group discussions (FGDs) were employed for Chemistry students to triangulate information gathered through interviews, observation and documentary analysis. The discussion aimed to examine students' experiences towards IBL based on performed learning activities. Some of the FGD questions were stated as follows: *how does learning through IBL differ from other learning practices? Explain the learning activities you are mostly engaged within the Chemistry lesson.* A total of four FGDs which took an interval of 40 to 50 minutes each were conducted using the English language. In maintaining the trustworthiness of the qualitative data, the study ensured credibility by triangulating information using multiple sources of data including interviews, FGD, observation, and documentary analysis. Thick descriptions of the context and participants ensured the transferability of the findings whereby, thorough descriptions of the research processes enhanced the dependability of the study. Confirmability was achieved by presenting participants' voice quotes made during interviews and FGDs.

Data analysis techniques

The qualitative data were analysed using thematic analysis, a technique designed to identify, organise, and interpret patterns of meaning (themes) across the dataset (Braun & Clarke, 2012). This process involved six stages, as suggested by Braun and Clarke (2006). First, the researcher familiarised themselves with the data by immersing in the textual data, reading and re-reading interview and FGD transcripts, and listening to audio recordings. The second stage involved generating initial codes, which helped in identifying and labelling data relevant to the research question. In the third stage, the researcher searched for themes by actively reviewing the coded data to identify areas of similarity and overlap between codes. The fourth stage required reviewing potential themes by re-reading all the data to ensure that the coded themes meaningfully captured the entire dataset. The fifth stage involved defining and naming themes, selecting extracts to present and analyse. Finally, in the sixth stage, the report was produced by logically and meaningfully connecting the themes (Braun & Clarke, 2006, 2012).

The coding process was conducted by the first author and cross-checked by co-authors by selecting phrases and sentences that form the building blocks for the anticipated themes according to the research objective. The agreed coded information was benchmarked in view of the objective. Observation data was thematically coded whereby, field notes collected using a pre-determined observation guide were read repeatedly to capture information for supporting themes. Observation indicators examined teachers' preparedness for the lesson in line with IBL practices and students' engagement in learning by connecting prior knowledge, asking questions, carrying out investigations, collecting and analysing data, interpreting, and drawing conclusions.

Findings and Discussions

This study aimed to explore Chemistry teachers' and students' instructional strategies employed as opportunities for the practice of IBL. Findings revealed that instructional practices demonstrated by both teachers and students to reflect on the potential for the implementation of IBL included performing practical activities, conducting discussions and presentations and questioning and answers. The findings for these themes are presented as follows:

Performing practical activities

The findings of the study revealed that the potential for IBL can be demonstrated when students are engaged in conducting practical activities. For example, through interview, one of the Chemistry teachers (T3) from school A said that:

> I always perform demonstrations and thereafter students use the procedures to perform practical activities in the laboratory. Students interpret procedures and carry out scientific investigations. When students are engaged in performing practical activities on their own, they can improve their way of thinking, analysing and presenting the findings (Interview, Chemistry Teacher T3 at school A).

In addition, a Chemistry teacher (T5) from school A elaborated on the opportunities for Chemistry practical activities in implementing IBL by proclaiming that:

> When performing practical activities, students become creative learners. By doing these activities on their own, students develop curiosity and can construct new information on specific Chemistry concepts and relate its application to their real-life situations (Interview, Chemistry Teacher T5 at school A).

Findings from teachers' responses demonstrate that practical activities are deemed essentially opportunities for the implementation of IBL. As asserted by Chemistry teacher (T3) responses, when students are engaged in scientific investigations, they can think about given procedures, perform activities, record data, analyse, interpret and present the findings. These skills are considered important in increasing students' critical thinking. As voiced by the Chemistry teacher (T5), when students perform practical activities, they increase chances for the occurrence of IBL and develop curiosity and the ability to construct and apply the acquired knowledge in real-life situations. Engaging students in practical activities is likely to promote the development of SPS and critical thinking skills.

Findings from Chemistry teachers' interviews on the potential of practical activities in implementing IBL were also evidenced by students through FGD. For example, a student (S6) from school C said that:

> ……. we mostly performed practical work. For example, in the preparation of Oxygen, the teacher demonstrated first and a few of us repeated the same demonstration in front of the class for our fellow students. Thereafter, we performed practicals by ourselves by using the given procedures in a textbook (FGD, student S6 at school C).

In addition, a student (S4) from school A demonstrated an understanding of activities performed in the classroom by saying:

> There are several practical activities that we perform in the learning process. The teacher insists on performing practical activities using scientific steps. For example, when learning the topic of volumetric analysis, the teacher assigned us to prepare all the apparatus required for titration. We identified useful apparatus such as a burette, pipette and beaker. The teacher asked us about the use of each apparatus, then allowed us to read, interpret procedures and conduct practical works in the determination of molar concentration, molar mass, percentage purity, and atomic mass of an element in a given compound (FGD, student S4 at school A).

Findings from students' voices, through FGD elaborate on the potential of practical activities in supporting students' involvement in carrying out scientific investigations. As asserted by the student (S6), teachers use demonstration to guide students in doing practical activities correctly. Following the response by the student (S4), students can engage in learning when they prepare laboratory facilities, interpret procedures and perform practical activities. These findings imply that engagement of students in doing practical activities and exploration of both physical and chemical properties of substances seems to increase opportunities for IBL.

Findings through documentary review revealed an integration of practical activities that offer students opportunities to carry out investigations. For example, findings from teachers' T1, T2, T4 and T6 lesson plans indicated some practical activities to be performed by students. An example of practical activities involves investigating the effects of concentration on the rate of reactions, analysing whether the evolution of carbon dioxide gas (CO_2) from hydrochloric acid (HCl) varies with the sample size of calcium carbonate ($CaCO_3$) and finding out whether Methyl Orange (MO) indicators could be made from locally available hibiscus flowers. The summary of some of the IBL activities planned for students to engage with are presented in Table 1

Table 1

Practical Activities Indicated in the Teachers' Lesson Plans for IBL

Schools	Form	Sub-topic	Investigative activities
A	III	Factors affecting the rate of chemical reaction	Experimenting to investigate the effects of the surface area of $CaCO_3$ on the rate of evolution of CO_2 when added with dilute. HCl
B	III	Acids and bases	Carrying out chemical tests using litmus paper on the presence of acids and bases in mango juice and wood ashes.
C	III	The concept of hardness of water	Performing experiments to investigate the effect of hard water and soft water when washed with soap
D	III	Indicators	Investigation of the presence of MO indicator in flowers by preparing indicators from red, pink and yellow flowers

Table 4.1 highlights the practical activities through which students engaged in investigating Chemistry phenomena, involving various Chemistry concepts. These findings suggest that students can be engaged in different practical activities for active learning to develop curiosity and acquire higher-order thinking skills of analysis, synthesis and evaluation. As evidenced in research findings, engaging students in conducting practical activities to explore, explain and analyse the data obtained from the investigation process enhances the development of critical thinking skills. Similar findings were reported by Yakar and Baykara (2014) that inquiry-based laboratory practices are effective in developing SPS for the students involved in performing practical work. Smallhorn et al (2015) also assert that engaging students in IBL laboratory work promotes a sense of inquiry mind and has measurable impacts both on students' learning outcomes and their satisfaction with learning. In the view of social constructivism theory, practical activities with challenging problems enhance active learning and develop curiosity and

innovative thinking (Kibga et al., 2021; Wheatley, 2018). When students conduct investigations, the overall learning process becomes activity-oriented (Maro, 2013). Putri et al (2021) argue that practical activities foster the use of the SPS and provide opportunities for students to focus on the steps required to complete their investigations in becoming scientifically literate. As asserted by Molinero and Belart (2022), involving students in exploring investigation procedures fosters increased critical thinking and the development of higher-order thinking skills.

Engaging students in practical activities during IBL enhances understanding of both basic and integrated SPS (Crawford, 2014; Kasuga et al., 2022). The presence of well-equipped laboratory facilities in schools can increase opportunities for students to practice IBL by actively participating in scientific investigations, collecting and analysing data and subsequently presenting the findings. However, literature alerts that in some situations, some practical activities can have little impact on the realisation of IBL in a classroom context (Kibga et al., 2021; Kwitonda et al., 2021). Practical activities that rely heavily on factual-based procedures and detailed recipes for student recall have limited potential for fostering IBL (Kwitonda et al., 2021). For example, findings by Pérez and Furman (2016) reveal that, due to a lack of IBL knowledge, most science teachers do prepare practical activities that require students to memorise procedures. This implies that teachers have insufficient skills for innovating practical activities that feature the IBL characteristics. As revealed by Kibga et al (2021), practical activities should aim to promote scientific practices and offer students an avenue for experimenting and developing critical thinking and problem-solving skills. Therefore, Chemistry teachers can design practical activities that create avenues for students to think and carry out scientific investigations at different levels of inquiry in the process of constructing knowledge.

Participating in the discussions and presentations of Chemistry concepts

Findings through interviews, FGDs and classroom observations revealed that discussion and presentation of Chemistry concepts are also potential for the implementation of IBL. For example, one of the Chemistry teachers (T6) from school C held that:

> We have an opportunity to implement inquiry-based learning through discussions. During the discussion, students think about the given questions and share ideas to provide answers according to what they have discussed. After discussion, students explain the concepts learned through a presentation (Interview, Chemistry Teacher T6 at school C).

In addition, a Chemistry teacher (T5) from school A elaborated on the potential of discussion and presentation by asserting that:

> Through inquiry-based learning, I place students into small groups and provide tasks for students to work on. During the discussion, I normally give tasks that require them to think and find how relevant are the concepts to their real life. After discussion and preparing a summary, students make a presentation so that knowledge from both groups can be shared by all students (Interview, Chemistry Teacher T5 at school A).

The quotes presented highlight the learning practices of using discussion and presentation as potential strategies for implementing IBL. According to the responses from the Chemistry teacher (T5), providing opportunities for students to make presentations enhances their ability to share acquired knowledge and recognise the relevance of Chemistry concepts in real-life situations. These findings suggest that when discussions are guided by activities that encourage students to explore, investigate, and construct knowledge, they are more likely to foster IBL, thereby promoting critical thinking and a deeper understanding of concepts.

Findings from the analysis of teachers' schemes of work and lesson plans from schools A, B, C, and D showed discussions and presentations as teachers' common approaches used in teaching and learning. For example, in school C, discussions and presentations enabled students to elaborate on the raw materials for the preparation of ammonia and its corresponding properties. Likewise, findings from classroom observations revealed that students in small groups of 4 to 6 use questions provided by the teacher to carry out discussions and make presentations on different concepts of the subject matter. It was further revealed that students used guiding questions in a lesson for brainstorming and exploring concepts related to specific sub-topics under discussion. For example, at school C, the discussion where the core learning activities for the preparation of ammonia are as shown in the extract of the lesson in Figure 2.

Sub-Topic: Ammonia

Specific Competence:
To enable students have the ability to describe the properties of ammonia

Guiding Questions for Discussion

i. What are the raw materials for the laboratory preparation of ammonia?
ii. Write a balanced chemical equation for the industrial preparation of ammonia on a large scale.
iii. How can you prepare small-scale ammonia in the chemistry laboratory?
iv. State the properties of ammonia

Lesson Development

Stage	Teaching activities	Learning activities
Introduction	Reviewing the previous lesson about Nitrogen through questions and answers	Students should respond to questions by reviewing the lesson about Nitrogen.
New knowledge	Formulating groups and guiding students to discuss the given questions and make presentations.	Students should discuss in groups of six each of the questions and present the answers discussed.
Application	Guide students to explain the chemical test for Ammonia	Students should explain the chemical test and alkaline properties of Ammonia.
Reflection	Summarising the lesson through questions and answers on general properties of Ammonia.	Students should explain the general properties of Ammonia.
Consolidation	Providing questions as a class assignment to name other chemicals used to prepare Ammonia	Students should respond to the questions as a class assignment.

Figure 2: *A lesson extract on the preparation of ammonia at School C*

The lesson extract in Figure 2 shows that discussions and presentations were the strategies used by students in searching for answers to the given questions in the laboratory preparation of ammonia. As evidenced through classroom observations, discussions and presentations coupled with questions and answers strategy were used in reviewing previous lessons, introducing the new lesson, examining new knowledge and summarising the lesson. These findings imply that the engagement of students in explaining and analysing concepts for the preparation of Ammonia is likely to contribute to an increased understanding of concepts and ability to explain Chemistry phenomena in different situations. During FGD with students, similar views emerged to strengthen the potential use of discussions and presentations in the implementation of IBL. For example, one of the students (S7) from school C said that:

> We are involved in the lesson by presenting what we have discussed. When we have a discussion, we share our understanding of the concepts because we differ in thinking. This makes the class active. Any of the students from the group can make a presentation followed by teachers' comment on concepts that needs clarification (FGD, Student S7 at school C).

In addition, the Chemistry student (S6) from school A supported the potential of using group discussion for executing IBL by articulating that:

> We always have group discussions where we share knowledge with other students and one of us presents what we discussed in front of others. This activity enables us to learn many concepts and gives us confidence in explaining what we have learnt (FGD, Student S6 at school A).

Findings from student's perspectives indicate that discussions and making presentations are potential IBL practices in supporting students' thinking, sharing knowledge and building confidence for what they learn. As responded by students (S7), during discussions, the teacher can clarify some concepts for students to have a complete understanding. These findings suggest that discussion and presentations seem to be a suitable opportunity for implementation of IBL by enabling students to engage in explaining, analysing and interpreting information. Creating a learning environment for discussions that align with students' learning experiences is likely to promote students' cognitive skills for working with little guidance. Students' involvement in the discussion that prompts asking questions, investigating and presenting the results of investigations have increased opportunities for the social construction of knowledge. As evidenced in the findings, discussions and presentations guided by inquiry activities offer opportunities for IBL. These findings corroborate those revealed in a study by Tindangen (2018) on an inquiry-based learning model to improve higher-order thinking skills that, discussion and presentations are effective IBL activities in the preparations of scientific reports as students carry out investigations related to specific topics or sub-topics. Discussions foster students' development of higher-order thinking and the ability to generate learning evidence. Learning by integrating inquiry practices in students' discussion, makes easier understanding of concepts and creates curiosity and interest in learning (Chakim & Andayani, 2021; Wheatley, 2018).

Questioning and answers

Findings through interviews with Chemistry teachers revealed that questioning and answers are potential instructional activities for the implementation of IBL. For example, a Chemistry teacher (T3) from school A said that:

> I ask questions to make my students think and share their knowledge during learning. Once the knowledge is shared, I can select any student to respond to the asked questions. Students can also ask and answer questions among themselves to promote their thinking. (Interview, Chemistry Teacher T3 at school A).

In addition, the Chemistry teacher (T4) from school D supported the potential for executing IBL through questioning and answers by saying that:

> The activities that are performed in the class with students include questions and answers. I normally teach them and pose different questions for about five minutes so that they can think and answer those questions (Interview, Chemistry Teacher T4 at school D).

Based on teachers' views, the potential for IBL implementation is enhanced through questioning and answers that can offer students opportunities to think and share knowledge. From the Chemistry teacher's (T3) views, questioning encourages thinking for students.

Findings from classroom observations revealed that questioning and answers were the frequent IBL activities demonstrated by students during the learning process. For example, in one of the Chemistry lessons on the effects of surface area on the rate of reactions, the teacher asked the following questions; *why it is easy to cook chips rather than the whole potato?* In addition, in a sub-topic of factors affecting the position of chemical equilibrium, a student asked; *why other factors such as catalyst and surface area do not affect the position of chemical equilibrium.* Moreover, students asked; *how is the knowledge of chemical equilibrium useful in daily life?* These questions can make students think critically by reflecting on their daily life experiences as they search for answers. These findings affirm that using thought-provoking questions that are more predictive, analytical and evaluative can trigger students' ability to formulate other questions for further investigations.

In the light of the presented findings, students used the teacher's prepared procedures for conducting investigations whereby, the practice of posing questions was demonstrated by both. On such a stance, this study fits into the continuum of inquiry in three levels confirmation, structured, and guided inquiry. The study acts as a driving force in integrating skills for open inquiry into the curriculum to develop students into full inquiry. The findings indicate that using thought-provoking questions to question students can foster critical thinking and support the effective implementation of IBL. Questioning serves as the foundation for students' cognition and thinking during the teaching and learning process. Therefore, it is essential for teachers to understand the theoretical taxonomy of question-asking to guide students' reasoning processes, which is crucial for meaningful learning in IBL (Tawfik et al., 2020). Questioning practices that encourage students to engage in reasoning, gather information, and explain and interpret data contribute to the development of higher-order thinking skills (Crawford, 2014; Santoso et al., 2018). These findings align with those of Ibnu and Rahayu (2020), who argue that questioning is a key driver of students' thinking and an important factor in implementing IBL.

Lombard and Schneider (2013) support that IBL is driven by questions that can promote discussion with peers and the use of authentic resources. Using questions that require students to think critically increases chances for IBL by engaging students in the exploration of the subject matter and the construction of knowledge (Tawfik et al., 2020). Questioning in the classroom helps students to debate on issues and make concrete arguments supported with scientific explanations, consequently, improving their thinking skills. With scaffolding through questioning, students can formulate questions and ask other questions among themselves (Santoso et al., 2018). Encouraging students to ask questions and answer among themselves drives students to conduct authentic investigations.

However, various studies revealed that students struggle with questioning in line with IBL principles, making it hard to develop critical thinking skills (Farahian & Rezaee, 2012; Ibnu & Rahayu, 2020; Santoso et al., 2018). Ineffective questioning techniques are among the reasons for students' failure to ask thoughtful questions (Farahian & Rezaee, 2012). Findings have also indicated that teachers often ask low-cognitive questions with an emphasis on knowledge (Ibnu & Rahayu, 2020; Mustika et al., 2020). Questions that require students to memorise information have little impact on students' critical thinking skills. As revealed by Mustika et al (2020), divergent questions that call for multiple perspectives can stir up the IBL and development of higher-order thinking skills. Findings from these scholars imply that effective questioning in IBL challenges students' thinking to analyse, apply, synthesise and evaluate information. Ensuring questioning is an integral part of IBL, it can contribute to students' increased thinking capabilities. By reflecting on opportunities demonstrated through IBL, the inquiry practice more demonstrated in the course of learning includes posing questions, conducting investigations, collecting data and presenting learning evidence.

Conclusions and Recommendations

This study has found that there are activities conducted in Chemistry classrooms by teachers and students which are the potential for executing IBL involving performing practical activities, conducting discussions and presentations, and questioning and answering. Although studies conducted in Sub-Saharan countries state that IBL is less practised, teachers can increase contextual innovation for the learning activities to support IBL. This study recommends continued integration of inquiry activities in learning to cultivate students' development of critical thinking skills. Moreover, the findings of the study demonstrate that questions and answers are among the opportunities to practice IBL. Further, research can be conducted to examine teachers' competencies in questioning to support IBL practices.

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Integration of Digital Technologies into Primary School Science Education: Exploring Challenges and Craved Initiatives

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Abstract

The study explored the challenges and craved initiatives for adoption to enhance the integration of digital technologies into science education in Tanzanian rural primary schools. It employed interviews, documentary reviews, and observations to generate data. Data were analysed thematically. The findings show that limited technological facilities, little knowledge of integrating digital technologies, lack of priority to teach science and technology subjects practically, and teachers' negative attitudes impeded a successful integration of digital technologies. The study further revealed the establishment of e-resource centres, science curriculum content digitalisation, the introduction of digital technology science labs, and the digitalisation of teacher education as desired initiatives for adoption to enhance the integration of digital technologies. The study recommends a collaborative partnership between the government and interested local and international digital technology agencies for technical and financial support to address the challenges and implement the desired initiatives.

Keywords: *challenges, craved initiatives, digital technologies, science education, rural primary schools*

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Introduction

As we approach the third decade of the 21st century, the debate is on supporting the integration of digital technologies into science education. As such, the importance of integrating digital technologies into science education, particularly in primary schools in today's digital era, cannot be underestimated. Primary education is an integral part of basic education responsible for raising children for the forthcoming generation. Indeed, the youth with requisite digital literacy skills pertinent to bridging the global digital divide and helping them to navigate through the education system and socio-economic life are in high demand (Shehaj, 2022). The term digital technology is used in this study to mean diverse software and gadgets such as smart boards, laptops, tablets, e-simulations, and virtual labs integrated into the teaching and learning of primary school science education to empower pupils with digital technology literacy skills (Haleem et al., 2022).

Empirical evidence shows that digital technologies are inadequately integrated and used in science education in many rural primary schools across sub-Saharan African countries. As a result, the lion's share of primary school levers is less equipped with digital literacy skills that could enable them to interact meaningfully in an increasingly digital technology-led world (Delgado, 2023; John, 2024). This inadequacy calls for exploring the challenges and craved initiatives to be adopted to enhance the integration of digital technologies into Tanzanian rural primary schools. A plethora of research on integrating and using digital technologies into primary school science education has been conducted in high-income country contexts (See, e.g., de Vicente, 2024; Sandoval-Henriquez et al., 2024; Shvardak et al., 2024).

Studies in high-income countries have indicated promising integration of digital technologies into primary school science education due to various factors. These range from the availability of digital infrastructure and resources to teachers' training and attitudes, socio-economic stability, and successful implementation of Information and Communication Technology (ICT) policies. For example, a study by de Vicente (2024) on the level of digital technology integration into Spanish pre-primary and primary schools revealed that digital infrastructure was adequately available and integrated into science teaching and curriculum. The study also reported that there was no significant difference in terms of digital integration between urban and rural schools. The experience of high-income countries offers invaluable insights and ambition to improve schools' digital technology environment in low-income countries.

Empirical studies conducted in the Tanzanian context have mainly investigated the assessment of ICT integration as a pedagogical tool in secondary education, context-based approaches for ICT integration into secondary science subjects teaching and learning, preparedness of pre-primary teachers in integrating ICT in teaching and learning, integrating the use of tablets into secondary school teaching and learning, and challenges and opportunities for implementing ICT subject in primary education (Alihaji, at el., 2024; Bakari & Ali, 2023; Kassim, 2024; Ngodu at el., 2024; Tandika & Ndijuye, 2019). A few other studies that have focused on the integration of digital technologies into education have largely focused on secondary and university levels (Bitegeko et al., 2024; Bulugu & Nkebukwa, 2024; Peter, 2023).

These studies have generally demonstrated that digital technologies have not been satisfactorily integrated and used across education levels. However, across the urban and rural primary school settings, overall, these studies indicate that rural primary schools are more underserved in terms of digital technologies (See, e.g., Bakari & Ali, 2023; Delgado, 2023). This situation, therefore, calls for the need to examine the challenges and desired initiatives to be adopted to enhance the successful integration of digital technologies into primary school science education in the rural context of Tanzania. Nevertheless, little is known about the challenges facing the integration of digital technologies into science education, particularly in rural primary schools in Tanzania. The study explored the challenges and desired initiatives for adoption to enhance the integration of digital technologies into science education in the context of rural Tanzanian primary schools to address the knowledge gap.

This study contributes to the understanding of the challenges and craved initiatives for adoption to enhance the integration of digital technologies into science education in rural primary schools in Tanzania. This understanding may spur education policy and decision-makers in Tanzania to revisit the current approaches and strategies used to integrate digital technologies into primary school science education. Two research questions guided the inquiry:

i. What are the challenges facing the integration of digital technologies into science education in rural primary schools in Tanzanian?

ii. What initiatives should be adopted to enhance the integration of digital technologies into science education in rural primary schools in Tanzania?

Theoretical Framework

The study was guided by Activity Theory proposed by Engestron (2008). Originally, this theory was developed by Soviet Union-era researchers in the 1990s. Later, in 2008, Engestron advanced the Activity Theory (Keijo, 2014). Activity theory was considered suitable for this study for two reasons. First, it seems to be an effective lens for understanding the integration of digital technologies into educational systems. It is because several scholars researching technology integration into education have relied on this theory, which does not appear baffled by time (See, e.g., Dai et al., 2024; Keijo, 2014).

Second, it presents a framework for understanding the integration of digital technologies into primary school science education in the interconnectedness of six components: subject, object, tools, community, rules, and division of labour at systemic and individual levels (Gyasi et al., 2021). The theory argues that the integration of digital technologies into the activity system may result in contradictions that act as craved initiatives and catalysts for systemic change. The theory focuses on processing an object/objective (integration of digital technologies into primary school science education) to transform it into a desired outcome. The process requires a subject; an individual, or a group of people linked to a given activity.

Tools are the mediating artefacts from the external environment essential for achieving the activity outcomes. The community involves one or several individuals who divvy the objective with the subject. Rules represent challenges that constrain the integration of digital technologies into the context of the activity system. Division of labour delimitates how tasks, power, and status are divided among members of the community. Thus, *Activity Theory* offers a socio-cultural perspective that considers the fact that digital technology integration in primary school science education must be studied within the broader context and the teaching and learning settings in which it is located (Keijo, 2014).

The study adapts the basic elements of the Activity Theory to explore challenges and desired initiatives for adoption to enhance the integration of digital technology into primary school science education in terms of *subject* – primary school teachers and head teachers (their experience in teaching science subjects, instructional use of digital technologies, necessity of pedagogical competence and skills in digital technology). *Object* – integrating digital technology into primary school science education. *Tools* – digital technology facilities, availability, and associated problems. *Rules* – challenges, desired initiatives, and expectations. *Community* – government, digital technology agencies and partners at the local and international levels, teachers, school leadership, students, and ICT personnel. *Division of labour* – roles of government, teachers, students, and the support of school leadership. *Outcome* – successful integration of digital technologies into primary school science education.

Methodology

Approach and design

The study employed a qualitative research approach to capture the participants' perspectives through interaction in their natural environments. The researcher used the bracketing technique to reduce the limitations of this approach, such as the possibility of attaching researchers' bias to the findings and conclusions (Cohen et al., 2018). The study employed a case study design with schools as the main cases and participants as units of analysis. The choice of this design stemmed from the fact that data collected from multiple cases is considered more reliable and richer when compared with data from a single case. It also allowed the researcher to employ multiple sites to equate different perspectives on the study object (Yin, 208).

Study area

The study was conducted in six public primary schools purposefully sampled from three rural districts in Tanzania: Ileje, Momba, and Songwe. Before the study time from July to September 2024, the integrated rural development organisation and the education officer-SIDA integrated project report in Songwe region indicated that these districts were relatively the most destitute regarding digital technology integration in primary schools (EOSIP, 2023; IRDO, 2024). Two primary schools were sampled purposefully from each district. Each of these schools had teachers who had attended an in-service seminar on integrating digital technology into primary school science teaching and learning. The researcher believed that these teachers could offer rich information pertinent to the study problem. The district education officers assisted the researcher in identifying the schools in each district. As such, the selected study sites and participants provided rich data that could not be gained from other choices (Maxwell, 2013).

Sampling

The study used a criterion purposive sampling technique to recruit 18 participants. This sample size enabled the researcher to reach a saturation point at which further information became repetitive. Criterion purposive sampling helped to identify participants with rich and relevant data for the study (Creswell & Creswell, 2018). Study participants included six head teachers and 12 teachers. One head teacher was sampled from each school based on their administrative and leadership roles. Headteachers were also involved in the study as they were overseers of the implementation of ICT policy at the school level.

Two teachers were recruited from each sampled school to make a total of 12. Two criteria were used to select teachers. First, having attended an in-service training on the integration of technology into primary school science teaching and learning, as hinted earlier. Second, having at least 10 years of experience in teaching primary school science subjects. Teachers with this work experience offered insightful perspectives on the challenges facing the integration of digital technologies into primary school science education. They were well-positioned to envision and share the craved initiatives that could be adopted to enhance the integration of digital technologies into science education in the studied rural primary schools.

Ethical considerations

The researcher observed all the necessary ethical concerns as per the national guidelines for research ethics that are in line with in-country researchers and associates of the University of Dar es Salaam (UDSM). The researcher sought research clearance from the UDSM. Research clearance enabled the researcher to get research permits from the regional, district, and institutional authorities. With the help of research permits, participants' consent to be involved in the study was sought. The researcher upheld confidentiality throughout the study to conceal the participants' and schools' identities. As such, when presenting the findings, participants were anonymised using titles such as headteacher and teacher. Schools' names were masked using letters A, B, C, D, E, and F.

Data collection methods

Data were mainly generated through interviews corroborated with documentary analysis and observations. These methods helped to cross-validate the information collected from each data collection method. Therefore, any flaw in one method was addressed by the strengths of the other method (Yin, 2018).

Interviews

The interview method helped the researcher to delve into participants' experiences and perspectives on the challenges facing the integration of digital technologies into primary school science education. It also enabled access to information about the desired initiatives for adoption to enhance the integration of digital technologies. Their insights could not be captured through documentary review and observation (Cohen et al., 2018). A face-to-face semi-structured interview technique was adopted because of its flexibility in varying the order of questions and clarifying them when required. It also enabled the researcher to be focused. Interviews were guided by an interview schedule containing open-ended questions on the challenges and craved initiatives. This interview protocol was useful for probing and navigating from the planned questions to unplanned emerging issues (Creswell & Creswell, 2018). Interviews were conducted with head teachers and teachers in their offices to keep them relaxed. Each interview session took between 40 and 60 minutes. Interviewees' consent was obtained to tape-record the interviews to add on manual note-taking.

Documentary analysis

Documentary analysis was used to capture data related to current government efforts geared toward the integration of digital technologies into primary school science education. A documentary review schedule was used to facilitate the analysis of relevant documents that included the new draft of the 2023 national ICT policy in Tanzania, the primary school science and technology syllabus for standard III-VII of 2019 (STSPSE-STD III-VII), and the 2016 curriculum for pre-primary education (CPPE).

Observations

The observation method enabled the researcher to verify the self-reported data from interviews. The researcher employed the non-participant, semi-structured observation strategy to be present in the studied schools as an unobtrusive observer (Bryman, 2016). An observation schedule was used to guide the observations. It focused on context-related challenges facing the integration of digital technologies into primary school science education in the studied schools. Observations were carefully conducted to avoid interrupting schools' instructional activities. Before data gathering, senior academics from the department where the researcher works were asked to check the data collection instruments for validation purposes.

Data analysis methods

Documentary and observation data were analysed using the qualitative content analysis method. This method involved the categorisation of data and analysing qualitatively the frequencies of the data categories appearing in national ICT policy and curriculum texts. Interview data were analysed thematically following six steps by Braun and Clarke (2006). The thematic analysis enabled the researcher to produce, analyse, and report recurring patterns from the dataset. Data familiarisation involved transcribing verbatim all interviews and reading repeatedly interview transcripts and observation notes. A copy of the transcript was then sent through email to each participant to review and give feedback within one week. However, no changes were proposed by study participants.

Re-reading the transcripts enabled the researcher to capture initial concepts regarding the challenges and desired initiatives that could be adopted to enhance the integration of digital technologies into primary school science education. The next stage was to generate initial codes/nodes, which involved two cycles. In the first cycle, free nodes useful for exploring the dataset were generated. Initial nodes were generated deductively where the researcher used predetermined headings generated from the research questions. The first cycle was useful for organising data into two major topics, namely, challenges and desired initiatives that were generated manually. The major topics became the starting free nodes through which related data chunks were attached to produce relevant data extracts for analysis.

Since the initial free nodes could not inform the data meaning, the second cycle of coding was conducted to generate meaningful codes. Data extracts were read critically several times to capture their meaning. Recurring ideas meaningful to the study were noted. A word, sentence, or paragraph was used as a primary unit for the identification of codes that were labelled with a few words.

This process led to the third stage of searching for themes, which was done inductively. Codes and their data excerpts were re-read critically to identify ones with more unified concepts. The researcher grouped and merged them to generate a theme. The next step involved counterchecking and revising the themes against the whole dataset to determine whether all the information related to the study had been extracted completely and meanings captured accurately. Two researchers' colleagues were requested to countercheck whether or not each theme represented participants' voices correctly. Even though colleagues were satisfied with the developed themes, they advised the researcher to reduce and merge some of the quotations supporting the themes. Defining and naming themes involved describing and refining each theme to answer the research question. For each research question, four major themes were derived from data analysis. Finally, the researcher produced a report with key participants' voices in block quotations to illustrate the themes.

Findings and Discussion

Findings are presented according to the two research questions and main themes that emerged from the analysis of data. The major findings are discussed in relation to the theory that guided the study and other relevant literature and empirical studies.

Challenges facing the integration of digital technologies into primary school science education

Data analysis generated four main themes, namely limited technological facilities, little knowledge of integrating digital technologies as a pedagogical tool, lack of priority to teach science and technology subjects practically, and teachers' negative attitudes towards integrating digital technologies at lower education levels.

Limited technological facilities

Findings revealed that limited technological facilities were one of the challenges facing the integration of digital technologies into primary school science education. Participants explained that one could not find facilities such as tablets, digital science labs, and computers in the rural primary school context. One of the teachers said:

> Limited technological facilities constrain the integration of digital technologies into primary school science education. In my view, the

> successful integration of digital technologies needs facilities such as computers, tablets, digital science labs, and reliable power. It is very rare to find these tools for learning and teaching science in our rural primary schools. How can you integrate digital technologies into the teaching and learning of primary school science if you do not have these facilities? It is not easy *(Interview, Teacher 1, School A).*

The above quotation shows that the lack of adequate supply of digital facilities was a barrier to the integration of digital technologies into teaching and learning science in the studied rural primary schools. Findings from observations corroborated the findings from interviews. It was observed that none of the participating schools had, for example, digital science labs. Three desktop computers, one in each head teacher's office were found at schools A, C, and F. At school D, the researcher observed one tablet possessed by a teacher. However, on the one hand, head teachers whose offices had computers said that those computers were for administrative purposes. On the other hand, a teacher who had a tablet reported that she used that tablet for personal matters. It means that available computers and tablets were not for science teaching and learning. Rather, they were for office and personal use, respectively.

These findings can be attributable to various factors, such as the meagre implementation of the Tanzanian ICT policy for basic education, little government commitment, stumpy political will, and insufficient engagement of ICT stakeholders (Bitegeko et al., 2024; Delgado, 2023). Activity theory emphasises that there should be a constant supply of digital technology facilities to realise the successful integration of digital technologies into primary school science education. Regarding this, the government should develop a sense of political will to influence the availability of digital facilities in rural primary schools by engaging different ICT stakeholders and the private sector (Engestrom, 2008). The finding echoes that of Kafanabo (2024), who found that unreliable power supply was one of the challenges for using technology during school closure caused by COVID-19 in Tanzania.

The finding also aligns with the newly drafted Tanzanian national ICT policy of 2023, which acknowledges that "*Despite the achievements made by the country to develop the digital infrastructures, they are not adequate to provide efficient and affordable digital services*" (MoICIT, 2023, p. 31). However, the finding is contrary to UNESCO (2018), which emphasises that the availability of facilities for digital technology integration should be leveraged to speed up the achievement of the goals of the Education 2030 agenda. The finding implies that unless concerted efforts are made to ensure digital technology facilities are available in rural primary schools, the digital divide among primary school pupils will persist.

Little knowledge of integrating digital technologies into teaching

Findings indicated that despite the limited digital technology facilities in the studied primary schools, primary school teachers and head teachers reported having limited knowledge of integrating digital technologies as a pedagogical tool. For example, one of the head teachers commented:

> Apart from the insufficient supply of facilities, another challenge I see is related to our little knowledge of how to integrate digital technology as a pedagogical tool. I think it is because teacher training colleges in Tanzania where we are trained have not yet prioritised digital technology use in primary school science education pedagogy. *(Interview, Head Teacher 2, School B).*

The quote above suggests that inadequate training of head teachers and primary school teachers on how to integrate digital technologies into the delivery of primary school science education is a critical barrier facing the use of digital technologies in primary school science delivery. Participants associated this finding with their preparation in teachers' training colleges. The finding disputes the Activity Theory belief that underscores the importance of digital technology pedagogical competence as a prerequisite condition for the successful integration of digital technologies into primary school science teaching (Engestrom, 2008). The finding is also contrary to the study by de Vicente (2024) conducted in the Spanish context. De Vicente's study found a strong correlation between teachers' digital pedagogical competence and the use of digital technological tools. This finding suggests the need for strengthening primary school teachers' training in terms of the applications of digital technologies.

Lack of priority to teach science and technology subjects practically

Findings showed that practical teaching of science and technology subjects in the studied rural primary schools had not been given priority. Participants expressed that despite commendable government efforts to introduce a subject called 'science and technology,' which is taught from class three to six, this subject is taught theoretically. Another head teacher was captured saying:

> There is a lack of priority to teach science and technology subjects practically. The government did a good thing to introduce this subject in primary schools. Pupils learn science and technology subjects from standard three to seven. Even in pre-primary classes, pupils are taught the theoretical fundamentals of science and technology. But unfortunately, we teach this subject theoretically. We just teach

> pupils the basic parts of a computer and their functions theoretically *(Interview, Head Teacher 5, School E).*

The quotation above implies that the drive to teach science and technology subjects practically is low in the studied rural primary schools. Instead of pupils interacting and using real computers to develop digital technology literacy skills, they ended up developing imaginations on the way computers' hard and soft components, such as keyboard, monitor, Microsoft Word, and Microsoft Excel programmes, look like.

Findings from a review of the primary school curriculum and observation supported the interview findings. It was revealed that there was a science and technology subject that was taught in classes three through seven. This finding is demonstrated in the following extract captured from the primary school science and technology curriculum for standard III-VII: "*The science and technology syllabus for primary school education standard III-VII consists of technological skills, information and communication technology, experiments, and [...]. Using this syllabus, the pupil will develop [...] creative scientific and technological skills*" (STSPSE-STD III-VII, pp. iv & 1).

The curriculum further states, "*The teaching and learning of science and technology subject is based on [...] practical [...] aimed at helping the pupil acquire the target competencies. The teacher is expected to assess the pupil's ability to perform practical [...]* (STSPSE-STD III-VII, p. 4). Moreover, analysis of the pre-primary education curriculum also revealed that science and technology were emphasised in pre-primary classes. The curriculum states, "*In order to cope with advances in science and technology, especially in Information and Communication Technology (ICT), the curriculum should emphasise [...] and the use of ICT in the teaching and learning process* (CPPE, p. 2.).

However, the researcher observed that all of the studied primary schools did not have computer labs to facilitate the practical teaching of science and technology subjects. It means that teaching science and technology subjects practically was accorded less priority in the studied schools. However, if this situation is sustained, it may widen the digital literacy divide among primary school pupils (Sandoval-Henriquez et al., 2024). The finding is contrary to previous studies (See, e.g., Shvardak et al., 2024; Tandika & Ndijuye, 2019) that emphasise prioritising practice-base teaching and learning of digital technologies to empower pupils with digital literacy skills needed in the current digital age. This empowerment is vital not only for work-related skills and life at large but also for their continuing science and technology education through secondary and tertiary education levels (Shehaj, 2022). Similar findings were reported by David (2018), who found that several countries in Africa, such as Comoros, Burkina Faso, Niger Guinea, and Madagascar, do not have computer labs in primary schools to offer practical computer skills to pupils. The establishment of computer labs seems to be given priority in lower and upper secondary and higher education institutions.

Teachers' negative attitudes on integrating digital technologies at lower education level

Findings demonstrated teachers' unwelcome attitudes toward digital technology integration into rural primary schools. Their unwelcome attitudes were another barrier to the successful integration of digital technologies into primary school science education. Most teachers explained that their fear of integrating digital technologies was based on their worry that children's good morals would be spoiled through their exposure to digital technologies. One of the teachers commented:

> Many of us teachers as parents in rural areas are still not comfortable with our young children interacting with digital technologies not only in schools but also at home. We believe that if children start engaging with technological tools at an early age, it may expose them to immoral behaviours that may endanger their good moral standing (Interview, Teacher 11, School F).

The expression above suggests that teachers teaching science in rural areas appear to be laggards in terms of accepting the positive side of using digital technology for children in schools and at home. Nonetheless, despite the huge benefits of digital technology integration into primary school science education, it is still debatable about the proper ways primary school children can use the technology to minimise the resultant negative effects that can spoil their good morals. It is because the excerpt above presents some reservations against the integration of digital technologies into primary school science education. Such suspicion means that exposing children to digital technology may lead them to read inappropriate or immoral content that might be harmful to their behaviours. This finding echoes previous studies by Alcardo et al. (2019) and Ndibalema (2014). For instance, Alcardo et al. found that teachers' negative attitudes and beliefs were among the barriers to integrating and using digital technologies in teaching and learning. Similarly, Ndibalema, examining the teachers' attitudes towards using digital technologies as a tool of pedagogy, found that teachers had a low awareness of the potential of digital technologies in the teaching and learning process over its drawbacks. The finding implies a need to create awareness among primary school teachers in rural areas on the importance of digital literacy in the current digital-driven education.

Initiatives for adoption to enhance the integration of digital technologies into primary school science education in Tanzania

Data related to desired initiatives were analysed, giving four key themes: the establishment of e-resource centres, the digitalisation of science curriculum content, the introduction of digital technology science labs in primary schools, and the digitalisation of teacher education.

Establishment of e-resource centres

Findings indicated that one of the initiatives for adoption to enhance the integration of digital technologies into primary school science education is introducing e-resource centres. Participants argued that e-resource centres are useful for providing technical support and training for science subjects teachers and headteachers on matters related to the integration of digital technologies into primary school science education. One of the teachers said:

> In my view, establishing e-resource centres to support technically the integration of digital technologies into primary school science education is an important initiative that can be adopted. Such centres are also essential for providing digital technology integration training for head teachers and teachers (Interview, Teacher 3, School C).

The quotation above indicates that establishing e-resource centres can facilitate the smooth integration of digital technologies into primary school science education. Indeed, e-resource centres might contribute significantly to supporting the integration of digital technologies into primary school science education. This finding is in line with Marasinghe et al. (2024), who maintain that e-resource centres are a rich source of digital information for teachers and students who search for digital learning materials on top of the traditional teaching and learning of science. The finding also agrees with the Activity Theory that posits that e-resource centres serve as mediating artefacts solicited from the external environment to achieve the learning goals in primary school science education (Engestrom, 2008; Marasinghe et al., 2024).

Primary school science curriculum content digitalisation

It was revealed that the digitalisation of primary school science curriculum content was another desired initiative that can be adopted to enhance the integration of digital technologies into primary school science education. Participants explained that a digitalised primary school science curriculum is essential for addressing the pupils' current digital challenges. One of the teachers commented:

> One of the best strategies to promote the integration of digital technologies into primary school science education is to digitalise primary school science curriculum content. Digitalised curriculum content is critical for addressing diverse science learning needs and increasing primary school pupils' digital literacy skills needed in the current digital era (Interview, Teacher 12, School D).

The above excerpt suggests that a digitalised curriculum content for primary school science education could be suitable not only for attending to pupils' science learning needs but also for promoting digital literacy among them. This finding can be attributable to the aspiration of transforming Tanzanian education from a knowledge-driven society to an information and digital-driven society. The finding is in line with the 2024-2034 Digital Economy Strategic Framework (DESF) for Tanzania (MoICIT, 2024). The DESF notes that digital technologies have infused all facets of our socio-economic setting, including education. It is because the digital age is being embraced across the world, and there is also a dedication in Tanzania to adapt to the digital sphere. Adapting to the digital sphere can be achieved by capitalising on the desirable initiatives towards new horizons; our nation aspires to guarantee that the benefits of the digital age are reachable by all equally (MoICIT, 2024). It means that digitalising primary school science curricula content would enhance accessibility to the advantages of the digital era for primary school pupils in underserved rural settings.

Introduction of digital technology science labs in primary schools

The introduction of digital technology science labs in primary schools could create an opportunity to enhance the integration of digital technologies into primary school science education. Participants argued that digital technology science labs could make the learning of science at the primary education level more meaningful and inspire pupils to love science in the Tanzanian context. This view was captured by one of the head teachers when she said:

> In my view, the integration of digital technologies into primary school science education can be enhanced through the introduction of digital technology science labs in primary schools. Digital science labs have the potential to make the learning of science subjects at the primary school level more concrete, meaningful, and enjoyable. It is because they contain exciting simulations, images, videos, and other digital media formats available on disks or the internet. As such, they can attract more pupils to love science starting from primary through secondary education (Interview, Head teacher 6, School F).

The quote above implies that the government needs to mobilise joint efforts from different education stakeholders, partners, and the private sector both at national and international levels to ensure that digital technology science labs are introduced in primary schools. This initiative seems to be necessary in Tanzania because many students dislike science subjects, particularly when they join secondary education, claiming that such subjects are difficult (Fussy et al., 2023; Francis, 2024). Findings from the documentary review substantiated the findings from interviews. Analysis of the new draft of the 2023 National ICT policy in Tanzania showed that the policy recognises the introduction of digitalised simulation labs as one of the ventures that can be adopted to enhance the applications of digital technologies in education. These findings agree with Nieveen (2024), who argues that digital technology science labs have become a prerequisite for advancement in Science, Technology, Engineering, and Mathematics (STEM) education. They are imperative for empowering children with digital literacy and the high-level digital skills they require to succeed in their future scientific inquiries.

The digitalisation of teacher education

Findings revealed that the digitalisation of teacher education was another craved initiative for enhancing the integration of digital technologies into primary school science education. Participants believed that the digital divide among primary school teachers could be bridged when the teachers' training programmes are digitalised. As a result, all primary school teachers graduating from these programmes would be empowered with the requisite knowledge and skills for integrating digital technologies into their teaching. One of the teachers explained:

> There is a need to digitalise teacher education to bridge the digital divide among primary school teachers. Digitalised training programmes are critical for empowering student teachers with the necessary skills for integrating effectively and responsibly digital technologies in the teaching and learning process. Such programmes are also important for preparing pupils for the digital society (Interview, Teacher 8, School E).

The extract above implies that the digitalisation of teacher education programmes is one of the untapped initiatives that can be adopted to enhance the integration of digital technologies into primary school science education. It has the potential to empower the pool of future primary school teachers with the requisite digital competencies. The finding implies that unless primary school teachers' training is digitalised, the digital divide among primary school teachers may persist. This finding is attributable to the fact that primary school teachers have little knowledge of how to use digital technologies as a pedagogical tool, as reported in this study.

The finding echoes the Activity Theory that emphasises the need for pedagogical competence in digital technology as a precondition for instructional use of digital technologies. The finding is also in line with a study by Oreku (2022), who found insufficient teacher preparation for the development of digital-related skills was one of the barriers to the integration of digital technology into the teaching and learning of science. Similarly, Shvardak et al. (2024) argue that the increasing importance of digital technologies in education systems intensifies the demand to integrate these technologies into the professional preparation of teachers. It means that there should be concerted efforts dedicated to prioritising the incorporation of digital technology skills development in primary school teachers' training programmes.

Limitations and opportunities for future research

Although the findings may be plausible, the following limitations to this study suggest further research. First, the study examined the integration of digital technologies into primary school science education but with a major focus on challenges and craved initiatives. Studies that can investigate the root causes of the identified challenges are recommended. Second, the study revealed negative attitudes among teachers serving in rural contexts on the integration of digital technologies into primary school science education. However, it did not document the pervasiveness of this attitude across Tanzanian rural contexts. Future research should consider establishing the prevalence of this attitude across rural settings in Tanzania by expanding the sample beyond the one used in the present study.

Conclusions and Recommendations

The study explored the challenges and desired initiatives that can be adopted to enhance the integration of digital technologies into primary school science education in the context of Tanzanian rural primary schools. Findings show that the integration of digital technologies into primary school science education in the studied schools is faced with several challenges. They include inadequate technological facilities to support the integration of digital technologies into primary school science education and, petite knowledge among primary school teachers on how to integrate digital technologies into teaching science. Other challenges were a lack of priority to teach science and technology subjects practically and teachers' negative attitudes towards integrating digital technologies at lower education levels. Furthermore, the study has established that establishing e-resource centres, digitalisation of primary school science curriculum content, the introduction of digital technology science labs in primary schools, and digitalisation of teacher education are desirable initiatives, which, when adopted, could enhance the integration of digital technologies into primary school science education in the context of the studied primary schools.

Based on the findings, the study recommends the following for improved policy and practice. First, the Tanzanian government, through the Ministry of Education, Science, and Technology, should mobilise financial resources to ensure an adequate supply of digital technological facilities such as computers, tablets, and digital science labs in rural primary schools. Second, there is a need to digitalise primary school teacher education to bridge the digital skill gap existing among primary school teachers in Tanzania. Third, the local government authorities must prioritise regular conduct of awareness creation campaigns in rural areas on the importance of digital technologies for pupils in the current digital-driven era. Fourth, through outsourcing educational digital integration experts, head teachers in the studied schools should regularly organise school-based workshops on how to integrate technology into the teaching and learning of science using facilities available in schools.

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Relevance of Curriculum Content for Learning ICT-Mediated Teaching: Perspectives from Tanzanian Computer Science Student Teachers and Tutors

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Abstract

This study explored the perspectives of computer science student-teachers and tutors on the relevance of curriculum content for learning ICT-mediated teaching in Tanzanian diploma teachers' colleges. Using a qualitative multiple-embedded case study design, data were collected from 30 participants through focus group discussions, interviews, and document analysis. The findings indicate that both student-teachers and tutors consider the ICT curriculum relevant, particularly topics such as computer applications, networking, and programming languages, which support lesson planning, teaching, and assessment using ICT. The study concludes that effectively integrating these technological topics enhances ICT-mediated teaching skills among future educators. It recommends that teacher education institutions, including the Tanzania Institute of Education (TIE), embed these topics more comprehensively into syllabi for science and mathematics student-teachers, emphasising digital literacy and technical proficiency.

Keywords: *ICT curriculum content, ICT-mediated teaching, computer applications, networking and programming languages, computer science student teachers, future educators*

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Introduction

The increasing dominance of ICT-mediated teaching has transformed education worldwide, compelling teacher education institutions to prepare student teachers to integrate ICT effectively into their teaching practices (Sart et al., 2022). ICT facilitates seamless information exchange between instructors and learners anytime and anywhere (UNESCO, 2020), making it a crucial component of modern education. Recognised as a catalyst for education reform, ICT encompasses various technologies such as computers, digital media, online learning platforms, and artificial intelligence (Mbah, 2010; UNESCO, 2020). Studies highlight that ICT enhances real-life learning experiences, fosters student independence, and improves higher-order thinking skills (Afolabi, 2013; Pu et al., 2020). Moreover, social constructivist theory supports ICT-mediated teaching as it emphasises learner-centred approaches and knowledge construction through interactive tools (Bai et al., 2016; Carlos & Gadio, 2012).

Global organisations such as UNESCO and the World Bank advocate for ICT-mediated teaching to expand access to quality education, particularly for disadvantaged populations, including persons with disabilities, migrants, and refugees (Kumar & Tammelin, 2018; UNESCO, 2023). The Sustainable Development Goals (SDG-4) and the Education 2030 Agenda underscore the role of ICT in fostering equitable and inclusive education (Muasa, 2019; Harindranath & Liebenan, 2020). However, despite strong policy support, studies indicate that many student teachers remain reluctant to engage in ICT-mediated teaching due to inadequate training and a lack of confidence in using digital tools (UNESCO, 2023). This reluctance raises concerns about the preparedness of future teachers to integrate ICT into their pedagogical practices.

ICT-mediated teaching encompasses various modalities, including e-learning, blended learning, open and distance learning, and massive open online courses (MOOCs) (UNESCO, 2022). These approaches have become integral to global education systems in response to the evolving needs of 21st-century learners (Bai et al., 2016; Meredyth, 2021). The COVID-19 pandemic further accelerated the adoption of ICT in education, prompting governments to reinforce digital learning policies and infrastructure (UNESCO, 2021). Countries such as Sweden, the USA, Denmark, Japan, and Finland have implemented comprehensive national strategies to promote ICT in education, demonstrating its potential to enhance teacher-student interactions, innovative teaching methodologies, and student engagement (Assan, 2013; Pu et al., 2020).

In Tanzania, efforts to integrate ICT-mediated teaching into teacher education have gained momentum in alignment with the SDGs and national education policies. The country's engagement with ICT in education dates back to 1965, with significant expansion occurring in the 1980s following economic liberalisation ((Ministry of Education and Culture [MoEC], 1995; Ministry of Work, Transport, and Communication [MoWTC], 2016). The ICT Policy for Basic Education (2007) and the Education Sector Development Plan (2016/17–2020/21) underscore ICT's role in enhancing teaching and learning (MoEVT, 2007; ESDC, 2018). Since the 2000s, various ICT initiatives, supported by the Tanzanian government and international agencies such as the Swedish International Development Cooperation Agency (SIDA), have strengthened ICT-mediated teaching in teacher education (Anderson et al., 2014; TESP, 2020). Key projects, including the ICT in Teachers' Colleges and the ICT for Sciences and English Language projects, contributed to building ICT infrastructure and capacity in teacher training institutions.

Despite these initiatives, challenges persist. Many Tanzanian teachers' colleges struggle with inadequate ICT infrastructure, unreliable internet connectivity, limited access to digital resources, and insufficient training for both tutors and student teachers (Malima, 2010). Studies indicate that tutors often lack the requisite digital skills to model effective ICT use in pedagogy, which affects student teachers' ability to integrate ICT into their teaching practice (TESP, 2020; UNESCO, 2023). Additionally, the digital divide between urban and rural areas exacerbates disparities in ICT access, hindering equitable teacher preparation for ICT-mediated teaching. As such, a successful integration of ICT into teacher education requires a multifaceted approach that addresses policy implementation, institutional capacity-building, and professional development for educators (Harindranath & Liebenan, 2020). Research suggests that effective ICT-mediated teaching relies on comprehensive teacher training, access to high-quality digital content, and a supportive institutional culture that encourages innovation in pedagogy (Pu et al., 2020). Moreover, fostering a positive attitude towards ICT among student teachers is crucial to ensuring their readiness to use digital tools in their future classrooms (Winnans & Brown, 1992).

This study examines the effectiveness of ICT-mediated teaching in preparing student teachers for contemporary classrooms, with a particular focus on Tanzania's teacher education colleges. It explores the extent to which ICT is integrated into teacher training curricula, the challenges encountered in its implementation, and the strategies required to enhance its impact. The study is expected to provide insights for policymakers, educators, and researchers seeking to improve digital teaching practices in teacher education colleges in the Tanzanian context and beyond.

Problem statement and research questions

Despite progress in integrating ICT into Tanzanian teachers' colleges, several challenges persist. Limited access to ICT infrastructure and resources, particularly in rural and remote colleges, remains a significant obstacle (Masalu, 2018; Kihoza et al., 2016). Many institutions lack adequate computers, reliable internet connectivity, and well-equipped computer laboratories, significantly hindering both tutors' and student teachers' ability to engage with ICT-mediated teaching practices. This infrastructural gap widens the digital divide between urban and rural colleges, undermining efforts to ensure equitable access to ICT-enhanced education (Chirwa, 2018). In addition to infrastructural challenges, human resource constraints further complicate the effective implementation of ICT-mediated teaching. Most student teachers in diploma teachers' colleges have only received basic ICT training, leaving them underprepared to effectively implement ICT-mediated instruction in their future teaching roles (TIE, 2019). Although initiatives such as the ICT in Teacher Education Programme (ITEP) have addressed some of these shortcomings, comprehensive nationwide programs to train tutors in advanced ICT pedagogies remain insufficient (PO-RALG, 2020). This skills gap limits tutors' capacity to effectively support student teachers in mastering the use of ICT tools for teaching and learning (Ghavifekr et al., 2016). To address these gaps, the current study aimed to explore how student teachers can effectively learn ICT-mediated teaching during initial teacher education. In line with this overarching research objective, the study sought to answer two research questions:

i. What are the relevant topics of ICT curriculum content that could support student teachers' learning of ICT-mediated teaching during initial teacher education?

ii. How does the ICT curriculum content from each topic support student teachers' learning of ICT-mediated teaching during initial teacher education?

Literature Review and Theoretical Framework

Review of related work

Relevant topics in ICT curriculum content for learning ICT-mediated teaching

The integration of ICT into teacher education programs has gained prominence in computer science education. Key ICT curriculum topics include computer applications, networking, and programming languages. These topics are central to ICT-mediated teaching, aligning with curriculum demands and research on ICT integration (Anderson et al., 2014; Chirwa, 2018; Masalu, 2019; Barakabitze et al., 2020). Computer applications, including word processing, spreadsheets, and presentation software, are fundamental for developing digital teaching resources, lesson plans, and interactive content (UNESCO, 2022; Barakabitze et al., 2020). Networking topics, such as internet usage, wireless communication, and local area networks, are essential for teaching student teachers how to access and share online educational resources effectively (Masalu, 2019; Chirwa, 2018). Additionally, teaching basic programming fosters problem-solving skills and the ability to create custom educational software or apps, directly supporting ICT-mediated teaching (Anderson et al., 2014; Barakabitze et al., 2020).

How ICT curriculum content supports learning ICT-mediated teaching

ICT curriculum content supports learning by enabling the development of critical teaching competencies. Vygotsky's (1978) pedagogical stages—planning, presentation, generalization, assessment, and application—provide a theoretical lens for analyzing how curriculum content supports practicum activities and ICT integration. For instance, topics such as computer applications and networking facilitate the design of ICT-rich lesson plans, enabling teachers to integrate multimedia resources and interactive teaching aids (Rutto, 2017; UNESCO, 2022). Programming skills enhance teachers' abilities to demonstrate interactive educational tools, improving student engagement (Chirwa, 2018; Mazzuki, 2017). Networking skills support the use of internet-based platforms for collaborative learning and real-time feedback during teaching practicums (Masalu, 2019; Muasa, 2020). ICT tools also aid in formative and summative assessments, offering diverse methods to evaluate student learning outcomes (Douglas, 2014).

Teaching practicum activities, such as microteaching, peer group teaching, demonstration, and block teaching, play a vital role in enabling student teachers to apply ICT skills in real classroom settings. Microteaching allows student teachers to practice ICT-mediated teaching strategies in a controlled environment, focusing on feedback and improvement (Douglas, 2014). Peer group teaching encourages collaborative learning and peer feedback, enhancing the use of ICT tools for lesson delivery and classroom management (Muasa, 2020). The demonstration allows student teachers to showcase ICT applications, fostering confidence and proficiency in using digital tools (Mazzuki, 2017). Block teaching offers extended teaching practice, enabling student teachers to apply ICT skills in diverse classroom scenarios (Rutto, 2017).

Research gap and policy implications

Despite the growing emphasis on ICT integration, significant gaps remain in understanding how curriculum content supports ICT-mediated teaching during initial teacher education, particularly in Tanzania. Previous studies have predominantly focused on broader ICT integration strategies in the Global South, including Nigeria and Kenya, with limited exploration of Tanzanian contexts (Masalu, 2019; UNESCO, 2023). Existing research often overlooks the role of specific practicum activities, focusing instead on non-practicum methods for learning ICT-mediated teaching (Chirwa, 2018; Mazzuki, 2017). Additionally, there is insufficient evidence on the systematic evaluation of ICT curriculum content and its uniform delivery across teacher education programs (Barakabitze et al., 2020). Aligned with Tanzanian education policies (NECTA, 2021), this study emphasizes strengthening ICT curriculum content and integrating practical teaching components. It underscores the need for investment in teacher training programs focused on ICT integration, enhancements to curriculum content to better support ICT-mediated teaching, and emphasis on experiential learning through practicum activities. By addressing these aspects, this study contributes to curriculum reforms, preparing future educators to meet the challenges of ICT-mediated teaching during and after initial teacher education.

Theoretical framework

The study is guided by social constructivist theory. According to Vygotsky (1978), the social constructivist theory is a learning philosophy founded on the premise that, by reflecting on our prior experiences, we construct our understanding of the world we live in. People generate their own "rules" and "mental models" to make sense of our experiences. Learning, therefore, is simply the process of adjusting our mental models to accommodate new experiences. The use of pre-instructional concepts is part of social constructivism. Vygotsky (1978) explained the mental models of social constructivism. According to Vygotsky, there are two guiding principles of social constructivism. First, learning is a search for meaning. Therefore, learning must start with the issues around which student teachers actively try to construct meaning. Second, meaning requires an understanding of wholes and parts (Vygotsky, 1978). The parts must be understood in the context of the whole. The learning process focuses on primary concepts, not isolated facts. To teach well, we must understand the mental models that student teachers use to perceive the world and the assumptions they make to support those models (Vygotsky, 1978). Therefore, the purpose of learning is for an individual to construct their meaning, not just to memorise the "right" answers and regurgitate someone else's meaning.

Since education is inherently interdisciplinary, the only best way to measure learning is to assess parts of the learning process, ensuring it provides student teachers with information on the quality of their learning. For the constructivist, learning is not knowledge written on or transplanted to a person's mind as if the mind were a blank slate waiting to be written on or an empty gallery waiting to be filled. Theorists have argued that the construction of new knowledge in ICT is strongly influenced by prior knowledge, that is, conception gained before the point of new knowledge (Vygotsky, 1978). Specifically, this theory was used in guiding data collection on research questions one, and two, which aimed to explore and examine the prior experiences of computer science student teachers' learning ICT-mediated teaching through examining the relevance of ICT curriculum content for student teachers learning ICT-mediated teaching. To enhance both computer science and non-computer science student-teachers learning ICT-mediated teaching during initial teacher education in TCs. Also, the social constructivist theory is used to examine how ICT curriculum content be used by student teachers for learning ICT-mediated teaching during initial teacher education in Tanzania and elsewhere.

Methodology

Participants and study area

This study involved 30 participants, including computer science student teachers and tutors from four Diploma Teachers' Colleges (TCs) in Tanzania. These colleges were purposively selected from the Eastern, Central, Southern, and Northern zones of Tanzania. Participants were identified through a typical case sampling technique, which focused on individuals' excellence in ICT-mediated teaching practices. This excellence was evidenced by their ability to plan, implement, and evaluate lessons using ICT. Snowball sampling was employed to refine the participant selection, leveraging recommendations from peers and instructors to identify key contributors. Informed consent was obtained from all participants after explaining the study's objectives, procedures, and potential risks. Participation was entirely voluntary, and anonymity was ensured through the use of coded identifiers during data presentation.

Research approach and design

The study adopted a qualitative research approach within an interpretivist paradigm. This approach was deemed suitable as it enables a deep exploration of participants' experiences and perceptions of ICT-mediated teaching practices. The research utilised a multiple-embedded case study design, as recommended by Yin (2014), to facilitate an in-depth examination of the phenomenon across diverse contexts. Previous studies (see, for example, Pesambili, 2013; Pesambili & Mkumbo, 2018, 2024) have employed a qualitative case study design within an interpretivist paradigm to conduct in-depth investigations of socio-cultural practices, such as FGM in Tarime. These studies demonstrate the effectiveness of this design in capturing participants' lived experiences, making it well-suited for exploring ICT-mediated teaching in Tanzanian Diploma Teachers' Colleges. The interpretivist paradigm supported the exploration of subjective meanings, aligning with the study's aim to understand participants' lived experiences.

Data collection methods

Data were collected using three primary methods: focus group discussions (FGDs), interviews, and documentary reviews. FGDs provided a platform for collective insights from participants, enabling the exploration of shared experiences and diverse perspectives. Focus groups are valuable for providing a forum to discuss the diverse experiences and conflicting views held by participants (Pesambili & Novelli, 2021). Interviews were conducted to delve deeper into individual experiences and perceptions, ensuring a comprehensive understanding of the phenomenon. Specifically, one-to-one semi-structured interviews were used because they allow for in-depth exploration of individual perspectives, providing flexibility to probe deeper into participants' responses while maintaining consistency in the topics covered (See also Pesambili, and Novelli, 2021; Pesambili, 2024). Documentary reviews such as academic and pedagogy computer science syllabi for three-year diplomas for science and business studies complemented these methods by providing contextual and historical data on ICT-mediated teaching practices in the selected colleges. The combination of these methods ensured data triangulation, enhancing the reliability and validity of the findings. Each method was chosen for its relevance in capturing the multifaceted nature of ICT-mediated teaching practices.

Data analysis

Thematic analysis, guided by Braun and Clarke's (2006) six-step framework, was employed to analyse the data. This involved familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. Data were analysed manually to ensure a nuanced understanding of participants' narratives. Two researchers independently coded the data to enhance reliability. Discrepancies in coding were resolved through collaborative discussions, ensuring consensus. Issues of validity, reliability, and transferability were addressed by maintaining a detailed audit trail, member checking, and triangulating data sources. Ethical considerations were upheld throughout the analysis process, ensuring the confidentiality and integrity of the data.

Findings and Discussion

The purpose of the study is to explore the views of computer science student teachers and tutors on the relevance of curriculum content for learning ICT-mediated teaching in diploma teachers' colleges in Tanzania. The findings and discussions are organized into two key themes based on the research questions: identifying relevant curriculum content for student teachers learning ICT-mediated teaching, and understanding how these topics contribute to the development of ICT-mediated teaching skills among student teachers. The following sections provide detailed findings and discussions on these topics, highlighting their significance in enhancing the development of ICT-mediated teaching capabilities among student teachers.

Relevant topics in ICT curriculum content for learning ICT-mediated teaching

The computer applications

The findings demonstrated that computer science student teachers perceived that the computer application topic is relevant for them in learning ICT-mediated teaching. This topic helps them prepare lesson notes, exam result reports, and lesson presentations during classroom teaching, as revealed by the following quote:

> We used computer application topics during my initial teacher education to learn ICT-mediated teaching. The topics we used included Microsoft Word and Microsoft Excel for learning ICT-mediated teaching, like the preparation of lesson plans, schemes of work, and lesson notes. We use Microsoft Excel topic for preparation for the secondary school examination result reports. While writing the project report, we drew histograms and pie charts graphs for presentation and analysis of the project findings (Focus Group Discussion, Student Teachers from Teacher's College One: 27/08/2021).

A similar view on perceived computer applications as a topic relevant for student teachers learning ICT-mediated teaching was commented on by one tutor from Teacher's College Two. The tutor said computer applications are a suitable topic for student teachers learning ICT-mediated teaching because, in that topic, student teachers learn how to prepare lesson notes and present lesson slides through a PowerPoint program. A quote below verifies what the tutor said:

> The topics in the diploma syllabi that support me when teaching student teachers ICT-mediated teaching include Microsoft Presentation, Multimedia, file management, and Information technology. I use Microsoft presentation for preparing my lesson notes and teaching student teachers to practise preparation lesson slides. Also, I use file management and information technology content to teach student teachers how to properly store information on the computer and get awareness and scope of information technology knowledge for diploma student teachers (Interviews, Teacher Educator One from Teacher's College Two: 13/09/2021).

Similarly, findings from the computer science pedagogy syllabus, analysis show that computer application is a relevant topic for student teachers' learning ICT-mediated teaching. The syllabus states as follows:

> The teaching of the selected topics in the Information and Computer Studies syllabus is as follows: teaching of computer file management, the teaching of office application programs and multimedia, which includes explaining the importance of teaching and learning multimedia in Information and Computer Studies and describing different strategies in preparation of multimedia lessons and teaching database as an information system (Tanzania Institute of Education, 2020).

The findings indicate that student teachers' engagement with computer application topics—such as Microsoft Word, PowerPoint, multimedia tools, Excel, and database management—enhanced their ability to learn ICT-mediated teaching. These topics provided practical skills for creating and delivering multimedia-enriched lesson materials, improving the teaching experience. Document analysis reinforced these findings, identifying office applications, multimedia tools, and file management as core to ICT-mediated instruction. Conversely, their absence hindered ICT integration, highlighting their critical role in fostering technical proficiency and pedagogical effectiveness. These findings align with social constructivist theory, which emphasizes interactive, contextually relevant learning (Afolabi, 2013; Rutto, 2017). By enabling student teachers to incorporate ICT tools, computer applications foster engaging, collaborative learning consistent with Vygotsky's principles. Empirical studies support this. Kafyulilo (2015) highlighted their role in ICT-mediated teaching, while Chirwa (2018) found that proficiency in office applications helps teachers develop materials and analyze performance. Barakabitze et al. (2019) noted that multimedia tools enhance engagement and teacher confidence, and UNESCO (2023) underscored their importance in delivering interactive lessons.

However, Kihoza et al. (2016) cautioned that technical skills alone are insufficient, advocating for integration into broader pedagogical frameworks, such as TPACK. Baran et al. (2017) warned against over-reliance on technical skills, as an exclusive focus on applications may neglect learner-centred approaches and problem-solving. Thus, while computer applications are vital to ICT-mediated teaching, their effectiveness depends on integration within pedagogical frameworks. This aligns with social constructivist theory and addresses literature-identified limitations, ensuring student teachers develop both technical proficiency and pedagogical expertise for ICT-integrated classrooms.

The networking

The findings revealed that computer science student teachers perceived that the networking topic is relevant for student teachers learning ICT-mediated teaching. The computer science student teachers from Teacher's College Three supported this view during Focus Group Discussion (FGD) and noted that:

> We learn ICT-mediated teaching through networking topics in diploma TC. Networking topics like website design, web management, and web development are relevant to us while learning ICT-mediated teaching in colleges and schools. Both web design and development topics are relevant to our learning by doing ICT-mediated teaching and being able to practise teaching computer science subjects. (Focus Group Discussion, Student Teachers from Teacher's College Three: 16/10/2021).

A similar view on perceiving networking as a relevant topic for student teachers learning ICT-mediated teaching was remarked on by tutors from Teacher's College Two who said:

> The network, including internet access, is a key topic for teaching student teachers about ICT-mediated instruction. This topic is relevant because it enables student teachers to communicate with their peers and access Learning Management Systems (LMS). Furthermore, it involves practical activities, such as connecting computers to the internet, which are essential for student teachers to effectively learn ICT-mediated teaching (Interviews, Teacher Educator Two from Teacher's College Two: 30/09/2021).

Similarly, the analysis of the diploma computer science pedagogy syllabus shows the following:

> The teaching of the selected topics in the ICS syllabus is as follows: teaching of computer networking and the internet, which includes explaining the importance of teaching and learning computer networks, and the internet and analysing different teaching and learning strategies for teaching computer networks and the internet, and teaching web development (Tanzania Institute of Education, 2020).

The findings highlight the critical role of computer networking topics—such as internet systems, web design, development, and management—in enhancing student teachers' ability to learn ICT-mediated teaching. These topics provided essential skills for hosting and managing Learning Management Systems (LMS) and integrating

ICT tools effectively. Networking knowledge also supports collaborative, interactive teaching strategies vital for engagement in technology-rich classrooms. Conversely, its absence hindered student teachers' grasp of the technical and pedagogical aspects of ICT-mediated teaching, underscoring the need for comprehensive networking content in teacher education curricula. These findings align with Chirwa (2018), who emphasized the practical applications of networking in real-world teaching, demonstrating its role in preparing student teachers for modern educational environments. However, while technological knowledge is essential, Kihoza et al. (2016) argued that it must be integrated within broader pedagogical frameworks. They advocated for the Technological Pedagogical Content Knowledge (TPACK) framework, which combines technological, pedagogical, and content knowledge to holistically prepare student teachers for ICT-mediated teaching. Overall, the findings underscore the importance of networking topics in teacher education curricula. Beyond enhancing technical skills, these topics foster collaborative, interactive teaching strategies essential for ICT-integrated classrooms. Integrating them with broader pedagogical frameworks, such as TPACK, can further optimize ICT-mediated teaching and learning.

The computer programming languages

The findings showed that computer science student teachers perceived that the computer programming languages topic is relevant to student teachers learning ICT-mediated teaching. This is because, in the programming languages, they learn how to create calculators and different mathematical formulae. The student teachers from Teacher's College One noted:

> The topic of programming languages helped us to learn ICT-mediated teaching, including data presentation, system development, operating systems, visual basics, and algorithms. This topic teaches us how to design and create calculator program formulae for manipulating different Mathematics and to account calculations. These topics are part of computer programming language lessons in diploma teachers' colleges (Focus Group Discussion, Student Teachers from Teacher College One: 09/08/2021).

A close view of computer programming languages as a relevant topic for student teachers learning ICT-mediated teaching was stated by a tutor from Teacher College Three. This view is because it further explains the relevance of computer programming languages for student teachers learning ICT-mediated teaching. This view was verified during interviews with a tutor from Teacher College Three who stated as follows:

> Computer programming languages such as Java, Pascal, C, and C++ in the diploma computer science syllabus influenced my approach to teaching ICT-mediated instruction for school teaching. These topics require student teachers to engage in hands-on learning, applying ICT-mediated teaching in diploma-teacher colleges. I found this particularly enjoyable, as I guided student teachers through learning by doing (Interview, Teacher Educator Two from Teacher's College Three: 25/10/2021).

The findings above were similar to those revealed during the analysis of the diploma computer science academic syllabus, which reads as follows:

> The topic of C++ programming languages includes programming languages, introduction to C++ programs, data types, variables and constants, input/output, expressions and assignments, decisions, iteration, functions, arrays and strings (Tanzania Institute of Education, 2010).

The quotes highlight the role of curriculum content in enhancing student teachers' ICT-mediated teaching, particularly through programming languages like Visual Basic, C, C++, and Java. These topics equip student teachers with essential skills, such as troubleshooting technical issues and developing Learning Management Systems (LMS), strengthening their ICT competencies. Their inclusion correlates with improved ICT integration in instruction, while their absence hinders skill development, underscoring programming knowledge as crucial for addressing technical challenges and creating digital teaching tools. These findings align with Vygotsky's Social Constructivist Theory, which emphasizes interactive and relevant content for meaningful learning. The study further revealed that the ICT curriculum primarily emphasized technological knowledge—computer applications, networking, and programming. While these topics are vital for ICT-mediated teaching, their impact is enhanced when integrated with broader pedagogical frameworks, as argued by Kihoza et al. (2016) and reflected in the TPACK framework.

However, the curriculum's limited focus on pedagogy and content knowledge may hinder comprehensive teacher preparation. This aligns with Kafyulilo (2015), who stressed the importance of technological topics, and Barakabitze et al. (2020), who warned against prioritizing technology over pedagogy. UNESCO (2023) also advocated for balanced content to maximize ICT-mediated teaching effectiveness. As such, while programming, computer applications, and networking are essential for technical expertise, their integration with pedagogical frameworks is crucial for preparing educators for technology-driven classrooms. These findings reinforce the need for a balanced curriculum that incorporates technological, pedagogical, and content knowledge to equip student teachers for ICT-mediated instruction.

How ICT curriculum content supports learning ICT-mediated teaching

Participants perceived technological knowledge topics as instrumental in facilitating their learning of ICT-mediated teaching. During focus group discussions and interviews, student teachers shared examples of how topics such as computer maintenance and networking directly supported their learning. For instance, networking topics enabled them to understand information transfer processes, such as sending assignments and receiving feedback via ICT platforms. These practical applications underscored the importance of technological topics in fostering hands-on learning experiences. This finding aligns with the social constructivist theory, which emphasizes experiential and collaborative learning opportunities.

Programming topics also emerged as particularly relevant, with participants noting the practical skills gained through activities such as programming language exercises. These findings echo those of Njiku et al. (2021) and Masalu (2018), who identified programming as a crucial component of ICT-mediated teaching. The frequent use of programming activities, such as Moodle platform development, further demonstrated the relevance of these topics in preparing student teachers to integrate ICT into their teaching practices. Participants expressed a desire to apply these skills in secondary school classrooms, highlighting the transformative potential of programming topics in their professional development.

Despite these positive findings, the study also revealed gaps in the ICT curriculum, particularly the lack of integration of pedagogical knowledge. For example, while technological topics like programming and networking are relevant, they need to be paired with pedagogical strategies, such as classroom management in ICT-rich environments and designing ICT-mediated assessments. As Kihoza et al. (2016) and Barakabitze et al. (2020) emphasize, integrating TPACK into teacher education can ensure that student teachers are not only technologically competent but also effective future educators in ICT-mediated teaching contexts.

Policy and practical implications

These findings have important implications for curriculum developers and policymakers. First, the ICT curriculum should be expanded to incorporate broader pedagogical knowledge, including ICT-based classroom management, strategies for student engagement, and ICT-mediated assessments. Second, integrating the TPACK framework into Tanzanian teacher education programs could bridge existing gaps, offering a more holistic approach to ICT-mediated teaching. Lastly, teacher training institutions should emphasize experiential learning, such as microteaching and peer teaching, to help student teachers apply and refine their ICT competencies in real-world settings. To this end, while the study reaffirms the relevance of technological knowledge in ICT-mediated teaching, it also underscores the need for a more balanced curriculum that integrates pedagogical and content knowledge. Addressing these gaps would enhance teacher preparation for ICT-integrated classrooms across diverse contexts.

Conclusions and Recommendations

This study concludes that the ICT curriculum in Tanzanian Diploma Teachers' Colleges is highly relevant for preparing computer science student teachers for ICT-mediated teaching. Both tutors and student teachers value key topics—computer applications, networking, and programming languages—which collectively develop essential ICT competencies. Computer applications support lesson planning and assessment, networking enhances communication and collaboration, and programming enables troubleshooting and e-learning platform development. These complementary roles highlight the need for a balanced ICT curriculum to equip future teachers with diverse ICT integration skills.

To enhance ICT-mediated teaching, this study recommends integrating these topics comprehensively into initial teacher education, particularly for science and mathematics student teachers. Curriculum revisions should emphasise pedagogical strategies and practical ICT applications, such as simulations and data analysis, to strengthen digital literacy. Capacity-building initiatives through tailored training and workshops should improve ICT proficiency for tutors and student teachers. Policymakers must prioritise funding for ICT infrastructure to ensure equitable access to quality education, aligning with Sustainable Development Goals (SDGs). The Ministry of Education should extend ICT curriculum content to other disciplines, broadening its impact. Future research should examine the long-term effects of ICT training on classroom practices and explore integrating emerging technologies, such as artificial intelligence and cloud computing, into teacher education curricula to align with evolving digital demands.

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Overcoming Challenges and Negative Perceptions of Open Educational Resources in eLearning Management Systems in Tanzanian Higher Learning Institutions

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Abstract

While Open Educational Resources (OER) offer a valuable opportunity for academics to access educational content, their adoption in Tanzania remains limited. This paper examines the challenges that hinder the adoption of OER by the academics of Higher Learning Institutions in Tanzania. Data on experiences and challenges related to OERs were collected through a focus group of 10 participants from two institutions. The findings were further validated through an online questionnaire completed by 90 academics across seven institutions. The study identified key challenges, including a lack of skills, contextual relevance, awareness, and policies on OERs, as well as concerns over ownership, licensing, and copyright. To address these challenges, the paper proposes several strategies, such as establishing OER policies that specifically address contextual adaptation, copyright regulations, and capacity building. These measures would enhance the adoption of OER among academics in Higher Learning Institutions in Tanzania.

Keywords: *Open educational resources (OER), eLearning management systems (eLMS), academics, higher learning institutions, adoption challenges, mitigation strategies*

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Introduction

The integration of Open Educational Resources (OERs) into the blended mode of teaching, represents a strategic approach to modernising and enhancing higher education in Tanzania, as outlined in the latest guidelines of the Tanzania Commission for Universities (TCU, 2022). By leveraging OER, universities can meet the TCU's requirements, improve the quality of learning, and ensure that education remains accessible to all students, irrespective of their financial circumstances. OERs are freely accessible and openly licensed educational materials found in various repositories, platforms, and websites. OERs can be used, shared, and modified by education communities. OER encompasses a broad range of digital and non-digital resources, including textbooks, lecture notes, videos, interactive modules, quizzes, assessments, and more(Faton et al., 2023). They empower both educators and learners by supporting the principles of openness, collaboration, and lifelong learning. OER can significantly reduce the financial burden on students and institutions by providing free alternatives to traditional expensive textbooks and learning materials (AjiThKumar, 2014)

Institutions use eLearning Management Systems (eLMS) to manage and organise learning. eLMS offers features to categorise and structure learning contents logically and intuitively. eLMS provides a centralised platform where educators can upload, organize, and store learning content. One such type of learning content that can be controlled by eLMS is OER (Bhalalusesa, 2013). eLMS enables educators to control access to learning content based on roles and permissions. They can designate which content is accessible to specific individuals, groups, or classes. This ensures that sensitive or restricted materials are shared only with the intended audience. However, eLMSs are limited in sharing the learning content because many of them lack the learning materials to start with (Mohammadi et al., 2021). To increase the availability of learning content in the eLMS, institutions can turn it into an OER strategy. OER allow educators to customise and adapt resources to align with their teaching methods, curriculum goals, and student needs. With the freedom to adapt and remix OER, educators can experiment with interactive multimedia elements, incorporate open educational technologies, and feed the learning contents into eLMS.

Although OER have been around for a while still their adoption in eLMS for developing countries is very limited. The low-level adoption can be attributed to the proper awareness among academics (Mtebe et al., 2014; Samzugi et al., 2010). Proper awareness involves knowledge. Knowledge is more than just mainly information but the rules upon which information can be inferred to produce newer information. Academics may be informed about OER but do not possess the right knowledge about OER. It is important therefore to understand how academics perceive OER to formulate tools that can improve the usage of OER. This way the challenges can be found through means put in place to mitigate them. This paper is based on research conducted to unearth challenges faced by academics when adapting the OER in higher learning institutions. The paper explores opportunities and strategies to address the challenges academics face when integrating OER into their curricula.

A Review of Related Work

Numerous studies have examined various aspects of Open Educational Resources (OER) adoption, utilisation, and impact across different educational contexts. Mtebe et al. (2014a) investigated the perceived barriers to OER utilisation in higher education institutions (HEIs) in Tanzania. Conducted across 11 institutions, the study employed semi-structured interviews with 92 instructors and document reviews to identify key obstacles. Findings highlighted limited access to computers and the internet, inadequate bandwidth, absence of institutional policies, and insufficient skills in OER creation or usage as primary barriers. The study contrasts with previous research in Africa, revealing that issues like distrust, lack of interest in OER creation or use, and time constraints were not significant barriers in Tanzania. Mtebe et al. (2014b) explored broader challenges facing HEIs in Tanzania and other African countries, particularly the lack of quality teaching and learning resources due to deficits in tradition, competence, and experience in resource development. Despite the availability of free OER in the public domain, their uptake in Tanzanian HEIs has remained low. The study identified effort expectancy as a key factor influencing instructors' intention to use OER, while performance expectancy, social influence, and facilitating conditions played a lesser role. These findings provide valuable insights into the challenges affecting OER adoption.

Samzugi et al. (2010) explored OER usage at the Open University of Tanzania, revealing that both academics and students accept OER. However, the study reported slow adoption due to a lack of knowledge on proper OER usage within eLearning Management Systems (eLMS). Without adequate knowledge, institutions may struggle to realise the full benefits of OER, necessitating better integration strategies within eLMS platforms. Similarly, Ismail et al. (2019) examined OER awareness among first-year undergraduate students at the State University of Zanzibar (SUZA). An online questionnaire survey across three campuses found that over 40% of students had little to no exposure to available OER offerings. Although OER usage at SUZA was low, the study identified growth potential, particularly given the widespread use of mobile devices and ICT among students. Challenges to OER adoption included limited access, connectivity issues, and concerns about affordability. The study also emphasised the need to build the capacity of academic staff in OER integration.

Mubofu and Kainkwa (2023) investigated Tanzanian academics' awareness, attitudes, and sentiments toward OER in two HEIs. Using a quantitative approach, they administered questionnaires to 52 purposively selected academics. The study found that while most participants had moderate awareness of OER and held positive beliefs about its benefits, some lacked the necessary training and support to integrate

OER into their teaching and research. The study recommended targeted training initiatives to address negative sentiments and promote OER adoption. Muganda et al. (2016) provided a comprehensive analysis of OER adoption within African Open Distance and eLearning (ODeL) institutions, focusing on workshops held at the Open University of Tanzania (OUT). Using a participatory research approach, the study convened two workshops with 28 academic staff and an OER Africa facilitator to assess the status of OER adoption. Findings indicated that while OUT staff were willing to engage with OER, they lacked sufficient awareness, skills, and competencies in OER creation, integration, and usage.

Loglo and Zawacki-Richter (2019) examined academics' perceptions and engagement with OER at a Ghanaian university using in-depth qualitative interviews. Participants viewed OER positively, particularly for addressing knowledge imbalances between the Global North and South. Concerns regarding OER quality emerged, with the reputation of the sharing institutions being a crucial factor in perceived credibility. The study also found that academics were informally engaging in OER-related practices, such as reusing and remixing educational content, though often without applying for appropriate open licences due to low awareness. These findings suggest a readiness for OER adoption but highlight the need for increased awareness and formalisation of open practices. Ujakpa et al. (2020) examined awareness, perception, and attitudes toward OER in relation to Sustainable Development Goal 4 (SDG 4), which aims to ensure inclusive and equitable education for all. The study, which surveyed 80 postgraduate students at the International University of Management in Namibia revealed high levels of awareness and positive perceptions of OER. The study recommended that universities actively promote OER creation to enhance the availability of relevant educational materials.

Wolfenden et al. (2019) explored OER utilisation in teacher education institutions across Mauritius, Tanzania, and Uganda. Using surveys and interviews with teacher educators and institutional stakeholders, the study examined how educators accessed and used OER, the factors influencing sustained engagement, and the impact on teaching practices. The findings indicated that many educators lacked knowledge of proper OER utilisation, largely due to weak institutional policies supporting OER integration. Lastly, Adala (2019) investigated the relationship between OER availability and the emergence of Open Educational Practices (OEP) at the African Virtual University (AVU). The study found that simply making OER available did not guarantee widespread adoption of OEP. Challenges such as insufficient institutional support, lack of necessary skills, and limited access to technology were identified. The study advocated for policies addressing training, ICT infrastructure, partnerships, and faculty motivation to strengthen OER adoption.

The literature provides a comprehensive overview of OER adoption, highlighting its potential to promote inclusive and quality education. However, several common challenges persist, including limited awareness, inadequate institutional support, and technological barriers. While studies have examined these challenges, there is still a need for effective strategies to systematically address them. Insights from existing research can inform the development of targeted interventions to enhance OER integration and utilisation in Tanzanian HEIs.

Methodology

This study employed a mixed-methods research approach, which integrates both qualitative and quantitative methods to enhance the depth and breadth of analysis. Mixed research paradigms can be applied concurrently, sequentially, or within a single study investigating the same phenomenon, offering a more effective, efficient, and robust approach compared to a single-method design (Creswell, 2014; Babbie, 2020). The qualitative part used data from in-person Focus Group Discussions comprising ten (10) academics from two academic institutions: the Open University of Tanzania (OUT) and the East African Training Centre (EASTC). For the quantitative part, a convenient sampling technique was used as all responses from academics who responded to the online questionnaire were used. There were a total of 90 academics from seven (7) institutions (OUT, EASTC, University of Dar es Salaam, National Institute of Transport, Mzumbe University, Institute of Accountancy Arusha and Institute of Finance and Management) who responded to an online questionnaire.

Thematic analysis was used to transcribe and identify the challenges discussed in the focus groups. Each theme that emerged from the analysis represented a challenge, which was then incorporated into the questionnaire. The variables from the thematic areas in the focus groups, as presented in the questionnaire, were primarily categorical. These included a 3-point scale (Yes, Don't Know/Maybe, No) and a 5-point Likert scale to measure importance (Not Important At All, Not Important, Neutral, Important, Very Important) and agreement (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree).

Python-built in packages that perform detailed analysis, including Pandas, NumPy, and Matplotlib were used. Data from the questionnaire were coded into Excel and imported into Python using Pandas and pre-processed using the NumPy package. A package of Matplotlib was used to visualise the findings in bar and pie charts.

Secondary data from the TCU report and various researchers who explored OER challenges in Tanzania were analysed. An exploratory analysis was conducted, where the results from these studies were compared with the responses from an online questionnaire. The insights gained from the secondary data were then incorporated into the Scholarly Personal Narrative (SPN) to help identify and establish strategies for overcoming the challenges identified.

Results and Findings

Demographics

Age

The perception of OER may be different according to the age group especially since both education and technology are concepts viewed from different angles by young and old people. Young people are usually not fearful of technology contrary to the perception of old people. One could argue that young people ought not to have more knowledge of OER than older people. The challenges faced by younger people in using OER may be different from those of old people. This trend is worthy of investigation to understand how best the OER is used. To understand this relationship, the age group of participants in the study was carefully observed to relate to the awareness and usage of OER. Figure 1 shows the distribution of the age group from the respondents.

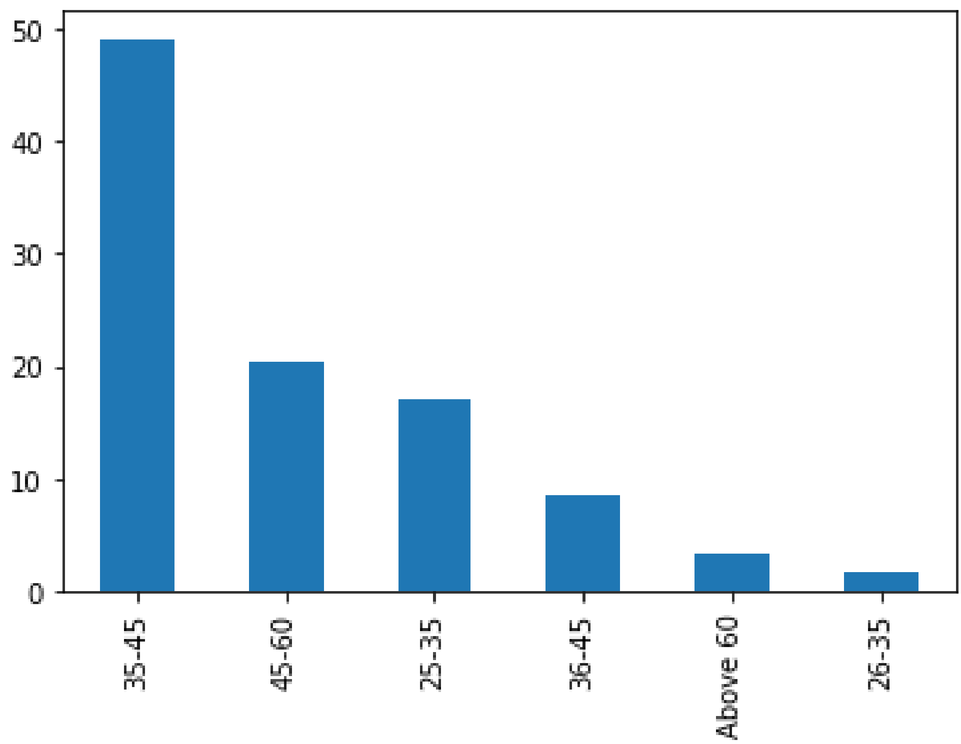

Figure 1: *Age of respondents*

Gender

Studies consistently highlight that gender disparities exist in accessing and benefiting from OER initiatives. Women, particularly in developing nations, often face challenges compared to their male counterparts. The solution on the other hand can differ between men and women. Before analysing the disparity of challenges between males and females their distribution in the study conducted must be known. Figure 2. shows the distribution of gender of respondents.

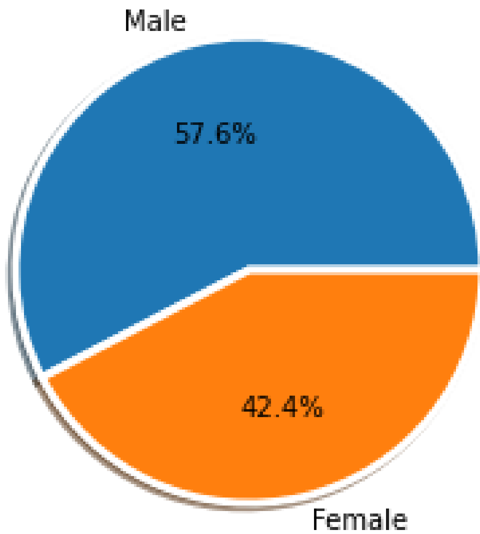

Figure 2: *Gender of respondents*

Challenges faced by academics in the adoption and utilisation of OERs

From the focus group discussions, several thematic challenges were identified. These challenges were incorporated into the questionnaire for academics to comment on their viability. They include: limited knowledge of OER (Open Educational Resources), fear of committing copyright infringement, lack of recognition of ownership, lack of contextual relevance in OER, insufficient pedagogical and technical OER skills, inadequate system integration, absence of a personalised instructional approach, and the prevalence of irrelevant materials on the internet. The identified challenges were included in the questionnaire, and academics were asked to provide their perceptions. A description of potential approaches to mitigate these challenges is provided after each challenge.

Lack of awareness and understanding of OER

Proper usage of OER can be attributed to a lack of awareness. The lack of awareness regarding OERs refers to a situation where individuals, institutions, or communities have limited knowledge or understanding of what OERs are, their benefits, and how to effectively use and access them. This lack of awareness can be seen among stakeholders in the education sector such as academics.

Academics' perspectives on OER awareness

The findings from the study revealed that most academics have some knowledge of what OER are and have used OER in their courses including video lectures from YouTube as indicated in Table 1. This is significant because it is clear that the rate of using the OER is not attributed to the knowledge of OER in Tanzania but must be controlled by other factors as well and calls for other factors to be considered as well.

Table 1

Academics' Awareness and Understanding of OER

No	Question	Yes	No
4	Do you know what is Open Education Resources (OER)?	72.9	27.1
5	Have you ever used OER in your Course?	59.3	40.7
6	Have you ever reused Learning Content downloaded from the Internet for teaching such as PDF, word, or video from YouTube, Google, or Yahoo?	93.2	6.8
8	Have you downloaded a question from the Internet and used it as it is without changing it?	50.9	49.1

While the academics acknowledged their awareness of OER, over 40% identified it as a significant challenge, as shown in Figure 3. However, knowledge of OER goes beyond merely understanding the term; it also encompasses the ability to effectively adapt and reuse OER in a meaningful and practical manner.

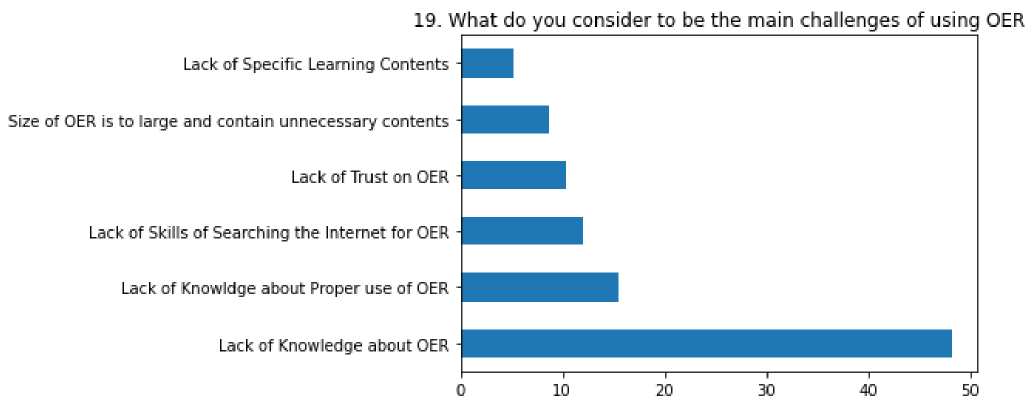

Figure 3: *Ranking summary of challenges identified from focus group*

Mitigating the lack of awareness about OERs

Addressing the lack of awareness surrounding Open Educational Resources (OER) requires concerted efforts from various stakeholders. Awareness campaigns promoting the concept, benefits, and potential of OER can reach a wider audience (South, 2023). These campaigns might include workshops, conferences, webinars, and online resources designed to inform and engage educators, students, policymakers, and other stakeholders. Offering training and professional development opportunities to educators, instructional designers, and administrators can enhance their awareness and capacity to effectively use and integrate OER in teaching and learning. Facilitating collaboration and networking among educators, institutions, and OER advocates can foster a supportive community. This might involve establishing OER communities of practice, online forums, and platforms for sharing experiences, resources, and best practices. Finally, policymakers can play a crucial role in raising awareness by incorporating OER into education policies and strategies.

Fear of committing copyright infringement

The fear of copyright infringement can have a significant impact on the adoption of OER. The complexity of copyright laws and the uncertainty surrounding the permissible uses of resources can discourage educators from utilizing OER. Educators may be hesitant to adopt OER due to the fear of inadvertently violating copyright laws. The fear of potential legal repercussions may overshadow the perceived benefits of using openly licensed resources, leading to a reluctance to explore and adopt OER.

Academics' perceptions of copyright infringement

The results show that most of the academics (over 85 %) in Tanzania are not familiar with the different types of Licences used in developing and reusing OER. As indicated in Table 2, 85% of academics do not know how to adapt the OER to new learning content. Table 2 also indicates that most academics do not check the Creative Commons (CC) license when adapting content from OER repositories. This is significant because it can lead to improper use of OER, potentially rendering them ineffective and causing institutions to abandon them.

Table 2

Knowledge of the Licenses used in OER

No	Question	No	Yes
26	Do you know what a Creative Common (CC) License is?	86.7	13.3
27	Are you knowledgeable about different types of CC licenses used in OER [Attribution (CC BY) –]?	88.1	11.9
27	Are you knowledgeable about different types of CC licenses used in OER [Attribution-Share Alike (CC BY-SA)]?	88.1	11.9
27	Are you knowledgeable about different types of CC licenses used in OER [No Derivatives (CC BY-ND)]?	86.2	13.8
27	Are you knowledgeable about different types of CC licenses used in OER [Attribution-Noncommercial (CC BY-NC)]?	86.2	13.8
27	Are you knowledgeable about different types of CC License used in OER [Attribution-Noncommercial-Share Alike (CC BY-NC-SA)]	85	15
27	Are you knowledgeable about different types of CC licenses used in OER [Attribution-Noncommercial-No Derivatives (CC BY-NC-ND)]?	85	15
28	Do you know how to add a CC License in developing OER?	86.7	13.3
29	Do you know how to adapt an OER with a signed CC License?	85	15

Mitigating the fear of copyright infringement

To eradicate the fear of copyright infringement in OER adoption academics require awareness, education, and support on copyrights (Butcher, 2015). There is a need to provide training and resources to educators to enhance their understanding of copyright laws, open licenses, and the permissible uses of OER. This can help dispel misconceptions and build confidence in utilizing openly licensed resources. Technologists need to ensure that OER repositories indicate the licensing information for each resource, making it easy for educators to determine the permissions and restrictions associated with the materials. Institutions need to offer guidance and support materials, such as best practices and Frequently Asked Questions, to assist educators in interpreting and complying with different open licenses. Awareness of open licensing and its benefits within educational communities should be promoted by institutional management and legal professionals. This can be achieved by emphasising how open licences enable the legal and ethical use of resources. Open content licences, such as Creative Commons licences, are commonly used for OER. These licences allow content creators to grant permission for others to use, modify, and share their work while stipulating certain conditions. Each CC licence has specific terms and associated icons. These terms include requirements like attribution, share-, non-commercial, and no derivatives. Understanding these terms and icons will help academics navigate the licensing requirements when using and adapting OERs.

Lack of recognition of ownership

The fear of losing authorship or recognition is a valid concern for some academics when it comes to OERs. Academics may worry that their contributions to OER will not be properly acknowledged. Since OER are openly licensed and can be modified or adapted by others, there may be a perception that authorship or intellectual property rights could be diminished or overlooked. There might be concerns that openly licensing their work as OER could diminish the uniqueness or value of their content, potentially impacting their professional reputation within their field. Some academics may worry that sharing their work as OER could be perceived as less prestigious or less impactful than traditional publishing, potentially affecting their chances of promotion.

Academics' perceptions of the lack of recognition of ownership

A large proportion of academics (69.5%) in this study showed that they do not check the owner of the OER before downloading the contents (Figure 5). Also, most of the academics (86.67%) do not know how to add a CC license to the OER while 85% of academics are not familiar with how to adapt learning content which has been signed with a CC license as shown in Table 2.

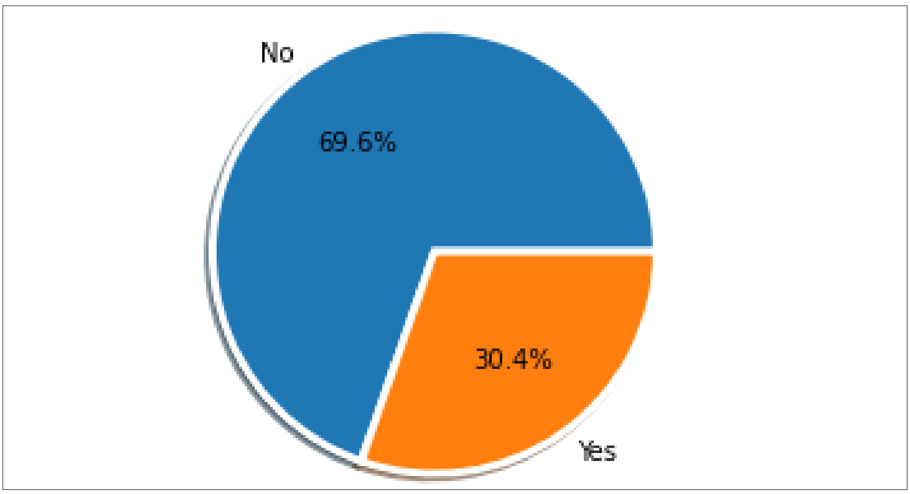

Figure 4: *Number of academics who check the CC license before using it*

Mitigating a lack of recognition of ownership

To address these concerns and alleviate the fear of losing authorship in OER, several strategies can be considered. OER repositories and platforms should ensure that proper attribution practices are in place, clearly indicating the authorship of each resource. Guiding how to attribute and give credit to authors can help maintain their recognition and reputation (Ismail et al., 2019). Academics can select licenses that preserve their desired level of control and ensure appropriate attribution. Academics should be encouraged to engage in co-creation efforts to improve collaboration. By actively participating in the development and improvement of OER, academics can maintain a sense of ownership and ensure their contributions are recognised. Academics can consider dual publishing, where they make their work available as both traditional publications and OER. This approach allows them to retain recognition in traditional publishing channels while also benefiting from the broader reach and impact of OER. The value of OER should be highlighted with the educational community and showcase examples of academics who have gained recognition, visibility, and collaboration opportunities by sharing their work openly. This can help alleviate concerns about the perceived loss of authorship and highlight the positive aspects of OER adoption.

Lack of contextual relevance in OER

The problem of context in OER adoption primarily relates to how OER are created, shared, and used. OER are often created by individuals or organisations from diverse backgrounds and contexts. While these can be valuable resources, they may not always align with the specific cultural, social, or educational needs of different regions or communities. This lack of contextual relevance can make it difficult for educators and learners to fully utilise OER in their specific settings.

Academics' perceptions of the lack of contextual relevance in OER

The findings show that a relatively higher number of academics (over 50%) reuse the OERs the same way they found it. That means they do not look at the context of the OER. If the OER was made for students in Malaysia their environment and curricula would be different from that of Tanzania and the OER ought not to be sufficient for their curricula.

Table 3

Reusing OER Without Contextualisation

No	Question	Yes	No
8	Have you downloaded a question from the Internet and used it as it is without changing	50.9	49.1

Mitigating the lack of contextual relevance

To deal with these context-related challenges, it is crucial to involve diverse stakeholders, including educators, policymakers, and local communities, in the creation, adaptation, and implementation of OERs (Kılıçkaya and Kic-Drgas, 2021). Collaboration and co-creation efforts can help ensure that OER is contextually relevant, adaptable, and effectively integrated into educational settings. Additionally, ongoing investment in infrastructure development and digital literacy initiatives can enhance access and support the sustainable use of OER.

Lack of skills (technology and pedagogy)

The lack of skills among educators can significantly affect the adoption of OERs. Educators need to possess the skills to effectively search, evaluate, and select appropriate OER for their teaching needs. Without the necessary skills to navigate the vast array of available resources and make informed decisions, educators may feel overwhelmed or uncertain about using OER. Also, OERs are often designed to be adaptable, allowing educators to customize them to suit their instructional methods, students' needs, and the local context. However, this process requires technical and pedagogical skills to modify, remix, or localise the resources effectively. If educators lack the skills or knowledge of relevant tools and technologies, they may find it challenging to adapt OER to their specific teaching environments.

Academics' perception of the lack of skills in using OERs

The findings in the study indicate that out of the five responses for the requirement of skills in adapting OER Most of the academics (94.8%) feel Skill is very important when adapting OER. The respondents ranked the different skills required using a 5 Likert important scale as shown in Table 4 and showed that all the skills are very important. ICT skills ranked first with a mode of (84.6%) in the skills identified to be important when adapting OER. However, a majority of academics noted that they have not been trained on how to adapt OER. This is in sync with the observation in part xx where most of the academics also showed less knowledge of the CC license used in OER as it is one of the skills required to adapt OER correctly. The academics (67 %) also reported that training of OER is important to reuse the OER well.

Table 4

Skill in Adapting OER

No	Skill	Mode (Highest Choice)	Percentage
22	Which skill is mostly required to reuse OER [ICT]	Very Important	84.6
22	Which skill is mostly required to reuse OER [Curriculum]	Very Important	73.3
22	Which skill is mostly required to reuse OER [Pedagogical]	Very Important	64.4
22	Which skill is mostly required to reuse OER [Just need time]	Important	43.6
22	Which skill is mostly required to reuse OER [Internet Search]	Very Important	56.9
22	Which skill is mostly required to reuse OER [Programming]	Very Important	40.7
22	Which skill is mostly required to reuse OER [Video Editing]	Important	41.0
22	Which skill is mostly required to reuse OER [Instructional Designing]	Very Important	53.9
22	Which skill is mostly required to reuse OER [Learning Psychology]	Important	46.2

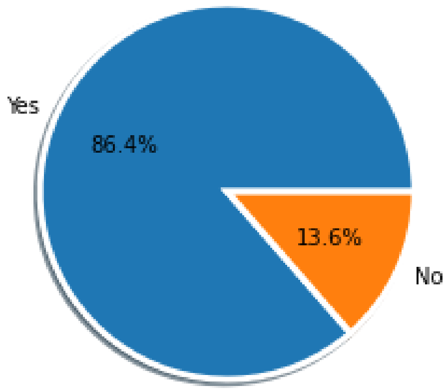

Figure 6: *Perception of academics on the need for OER skills training*

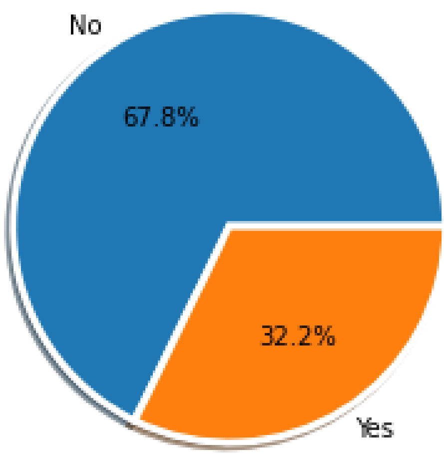

Figure 7: *The percentage of academics who have been trained in using OER*

Mitigating the lack of skills in using OERs

Some organisations provide financial and expert support in the field of OER development and promotion such as COL and UNESCO. These organisations offer financial support through various programs, projects, and initiatives that promote the development and use of OER. They provide grants and funding opportunities to individuals, organisations, and institutions for creating, adapting, and disseminating OER (Ossiannilsson et al, 2023). This financial support helps in producing high-quality OERs and sustaining OER initiatives. For example, the UNESCO-Commonwealth of Learning OER Chair Network supports the establishment of OER Chairs in various regions, fostering expertise and knowledge sharing. UNESCO collaborates with funding agencies and donors to mobilise resources for OER projects and provides expert support through its network of specialists in open and distance learning. They offer technical assistance, capacity building, and guidance in OER development, implementation, and sustainability. UNESCO and the Commonwealth of Learning share best practices, conduct research and facilitate knowledge exchange on OER topics. They also work with governments, educational institutions, and civil society organisations to foster partnerships and create a supportive ecosystem for OER.

Lack of OER policy

The lack of policy support can affect the adoption of OERs as they help raise awareness and understanding of OER among educators, institutions, and policymakers themselves. Policies provide a framework for institutions to support the adoption and integration of OER. A lack of specific policies or guidelines can result in a lack of institutional support, including dedicated funding, infrastructure, training, and incentives for educators. Policies can address copyright issues and provide guidelines on licensing practices for OER. The absence of such policies can create uncertainty and confusion among educators regarding the permissions, limitations, and legal aspects of using and sharing OER. Policies can encourage collaboration and resource sharing among institutions, educators, and stakeholders. They can promote the creation, adaptation, and sharing of OER across different educational contexts.

Academics' perceptions of the lack of OER policy

From the data collection, it was discovered that most of the academics are unaware of OER policy in their institutions. Some institutions such as The Open University of Tanzania have drafted OER policies but they have never been operational and that is why the academics are not familiar with these policies. As of 2024, there is no OER policy in the country although there are some developments that are being supported by HEET to formulate OER policy for the higher learning institutions.

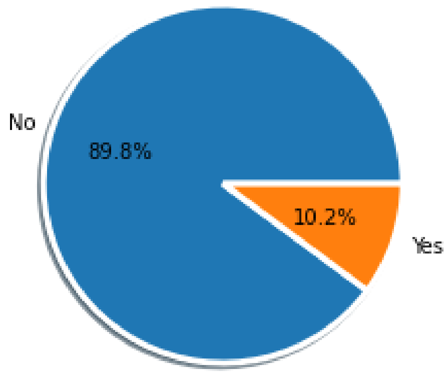

Figure 8: *Percentage of academics who are aware of OER policy in their institutions*

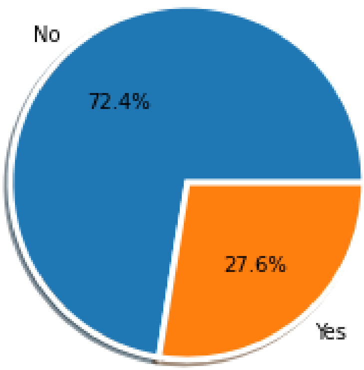

Figure 9: *Percentage of academics who are aware of OER policy in the country*

Mitigating the lack of OER policy

To promote OER adoption, it is essential to have supportive policies in place. Policymakers should work towards developing policies that explicitly support and promote the use and creation of OER(Muganda et al., 2016). These policies can address areas such as awareness raising, licensing guidelines, funding mechanisms, institutional support, quality assurance and reward mechanisms (Adala, 2019). Policymakers should involve diverse stakeholders: educators, administrators, content creators, and licensing experts, in the policy development process. Policies should be accompanied by advocacy and awareness campaigns to promote the benefits and opportunities of OER among educators, students, and administrators.

Lack of system integration

Interconnecting OER repositories with eLMS can be challenging. They may have different platforms, database structures, metadata schemas, and technologies. OER repositories may use different metadata standards or have inconsistent metadata practices. Interconnecting repositories with eLMS requires careful consideration of licensing compatibility, attribution requirements, and intellectual property rights. Top of Form

And finally Interconnecting repositories with eLMS requires infrastructure and ongoing maintenance to support the exchange and synchronisation of data. This may involve significant technical and financial resources.

Academics' perceptions of the lack of system integration

The number of academics who use OER in LMS exceeds those who do not use OER in eLMSs. Given that most academics lack proper skills in reusing OER there is a very high probability that they are not using them effectively. This explains why the number of individuals uncertain about using OER in eLMS is similar to the number who actually use OER in eLMS.

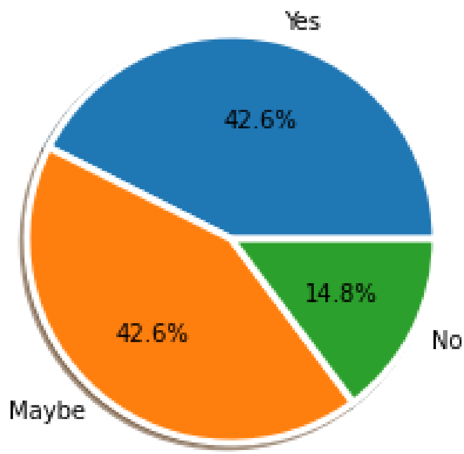

Figure 10: *Percentage of academics who use OER in the eLMS*

Mitigating the lack of system integration

Overcoming the difficulties of interconnecting OER repositories requires a collaborative approach, involving stakeholders from different sectors, standardisation bodies, and technology experts. It requires ongoing efforts to align technical systems, metadata practices, governance models, and sustainable funding strategies.

The best design for eLMS is to be able to integrate well with other external systems, including OER (Teng and Hung, 2013). It is important to note that the extent and ease of integration may vary depending on the specific eLMS version, configuration, and plugins available. When selecting an eLMS, it is recommended to evaluate its OER integration capabilities and consider the specific needs and requirements of your institution. Moodle eLMS which is by far the most popular eLMS in developing countries integrates well with OERs. It provides features like resource management, content sharing, and collaborative activities. Moodle allows instructors to upload OER directly into courses, create links to external OER repositories, and embed OER within learning materials. Other eLMS such as OpenEdx, Blackboard, Google Classroom, Canvas, etc also have some form of integration with OER.

Lack of personalised instructional approaches

Collaborative Learning and Personalised Learning are two pedagogical approaches that are used in higher learning institutions. Collaborative learning promotes social interaction, communication skills, and teamwork, while personalised learning supports individualised instruction, self-regulation, and autonomy. The choice between the two approaches depends on the learning goals, context, and the needs of the learners. OER materials are well suited for collaborative learning but Personalised Learning is not easily attained. Personalised learning focuses on tailoring education to the individual needs, interests, and pace of learners. OER, on the other hand, refers to freely available educational resources that can be used, shared, and adapted. Most of the OER contents are tailored to the context they were developed for and may lack personalisation when reused elsewhere.

Academics' perceptions of personalised instructional approaches

Personalisation is a teaching approach which requires pedagogical skills. From the table, it is clear that the academics (64.4 %) felt pedagogy to be one of the key skills which are required for using OER. Additionally, a large portion of academics indicated that OER skills training is very important. Since personalisation is a pedagogical skill and academics already perceive the skill to be very important in reusing OER, one can conclude personalisation to also important in using OER. However, most of the academics (67.2%) had indicated that they have not been trained on the skills of reuse of OER.

Mitigating the lack of personalised instructional approaches

The key area in mitigating the problem of personalisation in OER is improving the pedagogical skills of academics. This can be achieved through training on pedagogical approaches such as collaborative and personalised learning (Alamri et al, 2021). Once they are well trained academics can inject personalisation into the OER. Institutions should design learning experiences that integrate both collaborative and personalised learning elements. For example, students can collaborate in groups to create personalised learning paths using OER, with each group member contributing resources based on their interests and strengths. Academics can learn the skills to use OER to deliver instructional content outside the classroom, allowing students to engage with the material at their own pace. Classroom time can then be dedicated to collaborative activities, discussions, and personalised support.

Irrelevant material available on the Internet

The presence of irrelevant materials can have an impact on the adoption of OERs. The internet is made up of so many materials that are used by different groups. If low-quality or outdated resources are mixed with valuable ones in OER, it can undermine the credibility and trustworthiness of the entire collection. Educators may be hesitant to rely on the repository, unsure if they can find reliable resources within it.

Academics' perceptions of irrelevant learning materials

Quality OERs are made by academics who are good at instructional designing and pedagogical skills. Table 4 showed that the academics felt instructional design to be a very important skill (53.9) in reusing OER. In the previous part (4.2.8.1) it was also shown that pedagogical skills are also important. This shows that the academics know that high-quality learning OER is important. However, because most academics lack OER training, they are hindered from developing high-quality OER, resulting in a proliferation of irrelevant OER online.

Mitigation of irrelevant learning contents

It is worth noting that while OER is designed to be easily searchable, the process of finding the most suitable resources may not be easy. It is essential to review the content to ensure its relevance, quality, and alignment with your instructional objectives before incorporating it into your teaching or learning activities. Institutions need to Implement robust quality control measures to ensure that only high-quality resources are included in the repository. This can involve peer review processes, expert evaluations, or community-driven mechanisms for resource selection (Zamiri and Esmaeili, 2024). OER Repositories should ensure that resources are appropriately tagged, described, and categorised using standardised metadata practices. Mechanisms for user feedback and ratings should be Incorporated to enable educators and learners to share their experiences and evaluations of resources. The institutions should also continue to review and update the repository to remove outdated or irrelevant resources periodically to be aligned with current educational needs.

Conclusion and Recommendations

This study has identified several challenges academics face when using OER within eLMS. While significant progress is still needed to fully address these challenges, this study has also highlighted the potential for overcoming them. Effective strategies, involving all stakeholders—educators, institutions, policymakers, and the wider educational community—are essential for successful OER adoption in eLMS. This study proposes the following strategies to foster such adoption within Higher Learning Institutions (HLIs):

First, awareness campaigns and professional development programmes are crucial to educate educators, students, administrators, and policymakers about the benefits, value, and potential of OER. Organisations like the Open University of Tanzania, which have already made strides in this area, should showcase successful examples and highlight the positive impact of OER adoption on teaching, learning, and accessibility.

Second, developing and strengthening supportive policies is essential. Policymakers should develop and implement policies that promote the creation, use, and sharing of OER. These policies should address areas such as licensing, funding, quality assurance, resource sharing, and institutional support. Crucially, relevant stakeholders should be engaged in policy development to ensure their perspectives are considered.

Third, collaboration and partnerships among institutions are vital for wider OER use. Relevant authorities, such as the Tanzania Commission for Universities (TCU), the National Council for Technical Education (NACTE), and the Tanzania Commission for Science and Technology (COSTECH), should encourage collaboration among educators, institutions, and OER stakeholders. Partnerships between content creators, repositories, and educational institutions should be encouraged to facilitate the creation, curation, and sharing of high-quality OER. A culture of open collaboration and resource-sharing within the educational community should be promoted. Research donors should facilitate collaboration and knowledge exchange across countries and regions to foster a global OER community and encourage cross-cultural collaborations in OER development and adoption.

Fourth, institutions should provide professional development and training to educators to enhance their skills and knowledge in finding, evaluating, adapting, and integrating OER into their teaching practices, including how to link OER within eLMS. Training should address misconceptions and concerns related to copyright, licensing, and attribution, ensuring OER are shared with appropriate licences and acknowledgement of original authors.

Fifth, HLIs should enhance quality assurance mechanisms. Quality assurance frameworks and evaluation criteria for OER should be established. Institutions should encourage peer review, community feedback, and continuous improvement processes to ensure the quality, accuracy, and relevance of OER. Relevant institutional authorities should provide educators with guidance and resources to assess the quality of available materials.

Sixth, institutions should recognise the value of OER and provide support in terms of funding, infrastructure, and policy frameworks. They should encourage the integration of OER into institutional strategies, curriculum development processes, and learning management systems. Policymakers should recognise and reward educators for their contributions to OER and their innovative teaching practices. Relevant authorities should support research initiatives to explore the impact, effectiveness, and benefits of OER adoption, encouraging evidence-based practices and disseminating findings to inform decision-making and promote OER adoption.

Seventh, all stakeholders need to promote open licensing and resource sharing. Regulatory authorities, such as TCU and NACTE, should emphasise the importance of open licences, such as Creative Commons licences, to enable the free use, adaptation, and sharing of OER. University leaders should encourage educators to openly license their work and contribute to the broader OER community. Institutions should facilitate platforms and repositories that support the discovery, access, and sharing of OER.

Finally, institutions should promote accessibility and inclusivity, ensuring OER is accessible to diverse learners, including those with disabilities, different languages, and varying learning needs. Content developers should consider accessibility standards, alternative formats, and inclusive design principles in OER creation and dissemination.

By pursuing these strategies collectively and in a coordinated manner, OER adoption can be fostered, leading to increased access to high-quality educational resources, fostering innovation in teaching practices, and ultimately enhancing the overall quality of education. While this study has focused on the academic use of OER in eLMS, it is recognised that effective learner engagement with OER is also crucial. Future work will explore student perceptions of OER, particularly regarding context and personalised learning.

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