Science Education Initiatives in Tanzania: Review of the National Interventions From 1960's to 2020's

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Abstract
Investment in science education is crucial for the economic development of any country. This systematic review examines science education initiatives in Tanzania by focusing on the key areas of the interventions, challenges and strategies for improvement. A critical question is: What are the short, medium, and long-term strategies Tanzania could rethink for science education to foster the growth of a skilled and capable STEM workforce? The review incorporates projects' documents and reports encompasses the period from the 1960s to 2020s. The Education for Self-Reliance, School Science Project, Tanzania UNICEF-UNESCO Educational Reform Project, Secondary Education Development Programme, and Language Supportive Pedagogy are among the initiatives reviewed. Findings indicate the enhancement of the teaching resources, development and the implementation of curriculum, improvement of assessment systems, and infrastructure development as the key focus of the initiatives. The review highlights the persistent inadequate teacher qualifications, tensions between quantity and quality of education, a mismatch between education and job market needs, a shift from inquiry-based learning towards a more lecture-based instruction as the major obstacles in science education development in Tanzania. The review suggests improving teacher education, striking a balance between quantity and quality, bridging the gap between education and job market demands, and promoting inquiry-based learning. Despite the limitations of relying on existing literature and secondary data, the review provides insights into the current state of science education initiatives in Tanzania. It highlights the importance of continued investment in comprehensive interventions and sustainable initiatives to improve science education for the country's economic development.

Keywords: Comprehensive Review, Science Education, National Interventions, Initiatives

Background of the Study

Investment in science education is pivotal to the economic endeavours of any country (Ottenbaker & Klee, 2022). Despite efforts to improve science education in Tanzania, recent studies have highlighted challenges associated with it. Inadequate teacher qualifications (Umar, 2019), tensions between the quantity and quality of education, a mismatch between education and labour market needs, a shift from inquiry-based learning towards a more lecture-based instruction (Aslam et al., 2023) are some of these challenges. Teachers often lack subject expertise, which contributes to low academic performance (Holvio, 2022; Baker et al., 2009). Stakeholders recommend significant changes in science education, focusing on enhancing teachers' roles and motivation (Kapanadze et al., 2015). To promote science education, it is crucial to provide a specialised training for science and technology teachers (Klemenčič et al., 2023). The ongoing debate about the nature of science and science learning continues to shape perspectives on science education (Semali & Mehta, 2012).

Science, Technology and Mathematics (STEM) teachers play a critical role in students' learning experiences (Huang et al., 2022). Science and innovation can improve the teaching-learning process, requiring teachers to develop scientific and innovative thinking (Perez Sierra et al., 2022; Gao & Zhang, 2020). The integration of industry and education is crucial but lacks empirical research (Gao & Zhang, 2020). Inadequate and unsustainable funding has led to deteriorating quality of education in Tanzania (Semali & Mehta, 2012). Addressing challenges in education requires strategies to improve teacher qualifications, balance quantity and quality, align education with labor market needs, promote inquiry-based learning, and offer comprehensive teacher training. Despite various initiatives implemented in Tanzania, science education still faces challenges, and further improvements are needed (Aslam et al., 2023).

Objectives of the Review

The objective of this review is to provide a comprehensive overview of national interventions made from 1960s to 2020s to inform readers about the existing initiatives and propose interventions that can enhance their implementation, including the development plans. By critically examining the past efforts, this review seeks to contribute to the advancement of science education in Tanzania and support the effective implementation of various initiatives. A critical question driving this review is: What are the short, medium, and long-term strategies Tanzania could rethink for science education to foster the growth of a skilled and capable STEM workforce?

Methods

A comprehensive literature review was conducted to investigate Science education initiatives in Tanzania to pave a way of proposing possible interventions. The data were collected from official reports, academic publications, and government documents. A systematic search across academic databases, online repositories, and official websites using specific keywords related to science education initiatives, challenges, and interventions were performed. The criteria for selecting official reports, academic publications, and government documents for this review were based on their relevance to science education initiatives in Tanzania, specifically those that provided comprehensive insights into the challenges faced and the proposed future interventions. Thematic analysis was employed to analyse the gathered data and identify common themes, challenges, and possible future interventions. The study

acknowledges its limitations, including its reliance on existing literature and secondary data sources, which may introduce potential bias. Additionally, the absence of firsthand perspectives from stakeholders is noted. Nevertheless, the findings aim to provide a comprehensive overview of the current state of science education initiatives in Tanzania and serve as a basis for future research and policy-making in the field.

Review of Science Education During Between 1960's and 2020's

Since the 1960s, Tanzania has implemented a range of science education initiatives aimed at enhancing the quality of both primary and secondary education. Notable projects include the School Science Project and School Mathematics Project, Mpango wa Tanzania UNICEF/UNESCO (MTUU), known in English as the Tanzania UNICEF/UNESCO Primary Education Reform Project, the School Science Project of East Africa, and the Science Education in Secondary Schools Project. Additional efforts, such as the Teacher Education Assistance in Mathematics and Science, the Education II Project, and the Enabling Science Teaching and Learning in Rural High Schools in Tanzania Project, have also played significant roles. Other important initiatives include the Teacher Education Support Project, the Science and Technology in Higher Education Project, the introduction of a Diploma in Science Mathematics and ICT, and language-supportive teaching and textbooks in science and mathematics.

The School Science Project and School Mathematics Project

Formal science education in Tanzania began during the colonial era focusing on memorizing concepts and the works of foreign scientists, with little emphasis on contributions from local context. In 1967, Tanzania implemented the Education for Self-Reliance (ESR) policy, which aimed to develop three key skills in children: inquiry, learning from others, and critical thinking. This policy sought to align the educational system with national development needs (Rutayongororwa, 1987). The philosophy of "Socialism and Self-Reliance" aimed to integrate work and education, but initial efforts were inadequate, with the ESR system focusing more on passing national examinations than on applying knowledge in real-life contexts. Additionally, limited access to resources further impeded science education. The Musoma Resolutions in 1974 mandated the integration of work and education and the inclusion of manual work in the secondary school curriculum. Vocational secondary education was introduced to equip students with both academic and practical skills, preparing them for further education, employment, and productive participation in their communities.

In 1968 Tanzania borrowed educational materials such as "Thinking Science" from the USA and "Nuffield Science" from the UK (Osaki, 2007). These materials were adapted and developed into packages like "Elimu ya Kufikiri", the School Science Project of East Africa (SSP), and the School Maths Project (SMP). However, these programmes faced numerous challenges, including language difficulties, a lack of laboratory resources, issues related to examinations, curriculum constraints, teacher training, and the high cost of science equipment, along with a scarcity of textbooks, leading to their phase-out in the mid-1970s.

During a subsequent latent period, local materials were designed, but they tended to prioritize memorization over experimentation (Chonjo et al., 1996). This situation underscored the need for a shift towards inquiry-based learning and a stronger emphasis on practical application in science education in Tanzania. In 1995, Tanzania implemented a liberalization policy, which led to the emergence of several STEM projects aimed at reintroducing a practical approach to

science education. This resulted in many students lacking the necessary skills and aspirations for employment in industry or manufacturing after completing secondary schools (Semali & Mehta, 2012).

The Tanzania UNICEF-UNESCO Educational Reform Project

According to Mhaiki (1986), during the 1980s, science education in Tanzanian secondary schools faced several challenges, including declining student interest, poor examination results, and a shortage of qualified teachers. The emphasis was primarily on academic achievement rather than practical and career-oriented preparation, which diverged from a scientific approach to learning. Galabawa (n.d.) noted that the implementation of ESR in Tanzania encountered its own challenges. However, various actions were taken to align the education system with ESR's goals. These actions included establishing a curriculum development team, MTUU, and the School Science Project (SSP) of East Africa to advocate for primary education reforms, integrating practical activities in schools and colleges, assessing practical work alongside academic evaluations, and nationalizing educational institutions to increase government control. Ishumi (1994) emphasized that the Tanzanian government recognized the importance of science education in fostering technological development and societal progress. According to Mushi (1996) gender disparities in science performance were observed, with girls facing misconceptions and perceived lower abilities compared to boys, particularly in physics and mathematics. Female teachers viewed biology as the subject where girls excelled, while male teachers believed boys were most competent in physics. These perceptions affected girls' confidence and motivation in pursuing science. Cultural practices, ethnic rituals, and societal expectations were identified as factors influencing girls' false perception of their science abilities.

According to Kassam (2000), the guiding country policy emphasized the importance of education in promoting the collective welfare and achieving social objectives, such as equitable resource distribution and a sense of societal commitment. The restructuring of schools involved changes in teaching methods and attitudes, integrating theory with practice and mental with manual labour. Students' evaluation systems were aimed at considering academic abilities and contributions to the school and community. The orientation of education systems was geared towards rural life, with productive activities and student involvement in decision-making. The curriculum incorporated productive work for meaningful learning experiences, and examinations were de-emphasized.

Teacher Education Assistance in Mathematics and Science

Teacher Education Assistance in Mathematics and Science (TEAMS) introduced in 1995, supported by the Nuffic Foundation in the Netherlands, aimed to restructure the undergraduate teacher education programme at the University of Dar es Salaam (UDSM) to incorporate more practical teaching experiences and an understanding of the philosophy of science. TEAMS also developed in-service education and training programmes for science and math teachers, as well as a master's degree programme in science and math education. The project had practical contributions, such as computer-based micro-laboratory experiments (Tilya, 2003), teaching of probability (Kitta, 2004), and Micro-scale experimentation (MSE) in school chemistry (Mafumiko, 2006). The project successfully addressed challenges in secondary science education, expanded teacher training programmes and aligned with government educational plans. It improved curricula, teaching approaches, and programme design while emphasizing long-term strategies and sustainable development.

The project benefited from supportive institutional structures and career prospects. Despite the challenges, overall, the TEAMS project played a significant role in enhancing science and mathematics education in Tanzania.

The Secondary Education Development Programme

Tanzania's Development Vision 2025 recognizes the importance of education in fostering a well-educated society and achieving desirable attributes such as a high standard of living, peace, unity, good governance, and a competitive economy. Despite this vision, higher education in Tanzania faces significant challenges, including low student enrolment, gender disparities, inadequate funding, proliferation of unregulated tertiary institutions, and lack of recognition for academic programmes. Mkude (2003) pointed out that gender disparities in education become more pronounced as students' progress from primary to secondary levels in Tanzania. Girls tend to have lower academic performance, especially in subjects like mathematics, and there is an increasing trend of social inequalities in school selection, with more students enrolling in private secondary schools.

To realize the development vision, Tanzania aimed to transform from a least developed nation to a middle-income country with high levels of human development. Education is seen as a crucial driver for mindset transformation and addressing development challenges. The education system requires substantial restructuring to emphasize creativity and problem-solving skills. A strong economy and good governance are crucial for achieving the vision, and the emphasis is placed on basic sciences, mathematics, and science and technology education to enhance productivity and meet the demands of the modern era. Information and communication technologies are considered important tools for attaining the development vision.

According to Wedgwood (2005) the Secondary Education Development Programme (SEDP) in Tanzania aimed to improve access, equity, and quality in secondary education. It implemented various strategies, including constructing new schools, reducing fees, increasing scholarships, optimizing teaching resources, expanding distance learning, renovating schools for students with disabilities, providing grants, enhancing teacher training, and improving curriculum, library facilities and examination systems. Despite these efforts, challenges arose in ensuring qualified teachers, raising concerns about education quality. Tensions between quantity and quality. Higher education faced issues of access, quality, and funding, with overcrowded lecture halls and a mismatch between education and labour market needs. Incorporating vocational training encountered obstacles like teacher shortages and limited resources, prioritizing academic subjects over technical ones. Concerns existed about low numbers of high-achieving graduates, teachers lacking subject competence, and graduates lacking employable skills.

Science Education in Secondary Schools Project and the Science Teacher Improvement Project

The Science Education in Secondary school Project (SESS) established in 1996 and jointly funded by Tanzania and Germany, aimed to improve secondary science and mathematics education (Osaki, 2007). It focused on enhancing textbook access and laboratory facilities in 15 pilot schools and initiated a Training of Trainers Program. An internal review in 2000 identified minimal changes in classroom practices, leading to improved project management.

By 2003, SESS had produced trained resource personnel, many of whom became school inspectors, and was integrated into the Ministry of Education by 2006.

The Science Teacher Improvement Project (STIP), funded by GTZ and starting around 1995, shared similar goals with SESS but focused on introductory experiments before new topics. It conducted trial workshops in church schools and concluded in 2003, with its ideas incorporated into SESS and the Ministry of Education's in-service training.

The Education II Project

The Education II Project, funded by the African Development Bank, focused on developing in-service education materials and programmes to enhance the pedagogical knowledge and skills of STEM teachers in schools and colleges (URT, 2007). This project was mainly carried out by TEAMS graduates and produced educational packages that are still in use today. However, studies conducted after the projects ended revealed persistent weaknesses in practical science education Kibga (2013). The National Examinations Council of Tanzania suspended science practical examinations in O level due to resource constraints, leading to a shift towards theoretical teaching and a lack of practical skills among students. Similar problems were observed in teacher education programmes at universities, where teaching methods were predominantly theoretical (Ottevanger et al., 2005). The challenges included a lack of laboratories, poorly trained teachers, and insufficient technical support staff (Eskola, 2009). These factors negatively impacted student performance in science subjects. The need for systematic professional development programmes and improved infrastructure and resources in science education was evident during this period.

Enabling Science Teaching and Learning in Rural High Schools in Tanzania Project

Enabling science teaching and learning in rural high schools in Tanzania (ENSCIENCE) project, a collaborative effort between the University of Dar es Salaam, University of Dodoma, Swiss Federal Institute of Technology, and the Centre of Science and Mathematics Education at Rehovot, Israel, aimed to enhance science education for advanced-level (A-level) secondary education in Tanzania. It focused on developing integrated Chemistry modules for A-level science instruction and assessing their impact on scientific knowledge and analytical skills (William et al., 2014). Although funding from the Swiss Government Science Fund ended in 2012, the project yielded several conference publications. Schools that implemented the project's materials witnessed substantial improvements, including one school achieving top performance in A-level national examination results in 2015. Overall, the ENSCIENCE Project made significant contributions to science education in Tanzania at the A-level (William, 2012).

Teacher Education Support Project

The Japan International Cooperation Agency (JICA) implemented interventions in science and mathematics education in Tanzania. These interventions included training science and mathematics teachers abroad, developing practical and teacher guides, creating videos to support practical implementation in schools facing shortages, establishing in-service teacher training centres, implementing teacher education programmes such as the Teacher Education Support Project (TESP), providing science kits and micro-scale experiments, introducing science in secondary schools, and setting up laboratories in secondary schools across

Tanzania. These interventions aimed to enhance the quality of science and mathematics education in the country.

Science and Technology in Higher Education Project

The Science & Technology in Higher Education Project (STHEP) in Tanzania, launched in 2007, aimed to strengthen science education in higher education institutions. The project among others, addressed challenges of shortages of science teachers and technical personnel, and limited access to telecommunication facilities. Although the project encountered challenges, particularly regarding the high costs associated with training staff abroad, overall, STHEP made substantial contributions to the advancement of science education in higher education institutions in Tanzania. It improved access to quality education and resources in the field of science and technology, thereby fostering the development of human capital and supporting the country's socio-economic growth.

Following the STHEP, Tanzania implemented a retooling programme that utilized the ICT resources developed during STHEP to enhance the training of science and mathematics teachers in schools. The programme aimed to improve Science education by fostering collaboration between universities and schools, with universities taking on the responsibility of raising educational standards in schools. However, there is currently no available evaluation of the programme's outcomes.

Introduction of Diploma in Education-Science Mathematics and ICT

To combat the shortage of science teachers, Tanzania introduced a Diploma in Education-Science Mathematics and ICT (DESMICT) programme in 2014. The objective of this programme was to produce science teachers from O-level school finalists who could then fill teaching positions in schools. However, the programme faced challenges, and no students have graduated from it thus far. Consequently, the programme had to be transferred from the University of Dodoma to teachers' colleges. While the specific impact and effectiveness of the retooling programme and the Diploma in Science Education programme remain unclear, these initiatives demonstrate Tanzania's ongoing efforts to address the shortage of qualified science teachers and enhance Science education in schools. Evaluating and refining these programmes will be crucial for their success in improving science and technical education in the country.

Language Supportive Teaching and Textbooks in Science and Mathematics

The Language Supportive Teaching and Textbooks (LSTT) in Tanzania project was initiated in 2014 aiming to support students in transitioning from primary school to secondary school in Tanzania, where the language of instruction changes from Kiswahili to English. Many students face difficulties in learning due to low levels of English language proficiency (Brock-Utne et al., 2010). While private primary schools offer English-medium education, they are only accessible to a minority of students in urban areas who can afford the fees. LSTT is a collaborative effort involving three universities, namely the University of Bristol's Graduate School of Education, the University of Dodoma's College of Humanities and Social Sciences and Faculty of Education, and the Aga Khan University East Africa Campus' Institute for Educational Development. The project also partners with the Tanzania Institute of Education (TIE).

Previous research conducted by the University of Dodoma focused on developing bilingual classroom strategies for teachers of Standard 7 and Form 1 (Rubagumya et al., 2011). During this research, it was observed that the textbooks used in Tanzanian secondary schools were too challenging for Form 1 students to comprehend. This finding was replicated in studies of primary school textbooks in Ghana and Rwanda (Barrett et al., 2014; Clegg & Afitska, 2011), indicating that textbook design and publishing across sub-Saharan Africa face similar issues. In most African upper primary and secondary schools, students are expected to learn in a European language that is not their first language and is not commonly spoken in their communities. However, the textbooks used in these schools do not consider this linguistic context. They are written with a level of language complexity that would not be suitable in countries like the United States and England, where English is the first language for the majority of students. To address this issue, the LSTT project supported the development of five Form 1 textbooks (English, Mathematics, Physics, Chemistry, and Biology) that are accessible to the majority of Form 1 students in Tanzania.

These textbooks aim to serve as a model for designing books that consider the needs of second language learners. They are expected to be valuable for curriculum developers and publishers not only in Tanzania but also across East Africa and other English-speaking countries in sub-Saharan Africa. While textbooks play a crucial role in supporting teaching and learning, they are not sufficient on their own to improve the quality of education. Textbooks designed to be accessible to students have the greatest impact when they are in the hands of teachers who can implement teaching and learning strategies that support language acquisition. These strategies include encouraging student communication in both Kiswahili and English(Clegg & Afitska, 2011) allowing students to use Kiswahili to understand and process new ideas and express their own thoughts in both languages through spoken and written English. This involves providing opportunities for reading, writing, speaking, and listening in the classroom.

The University of Dodoma's previous project successfully transformed the teaching methods of Standard 7 and Form 1 teachers to better support English language concept learning through short workshops and follow-up support. As a result, the LSTT project examined existing in-service training programmes to determine the integration of language supportive pedagogy and identify opportunities for its enhancement. For example, a study by (William & Ndabakurane, 2017) revealed that in Tanzania, learners struggle with mathematics due to the sudden shift from Kiswahili to English terminology upon entering post-secondary education. This language barrier, coupled with the complexity of mathematics textbooks, poses challenges for Tanzanian secondary school students.

Key Findings From the Review

During the period from the 1960s to the 1990s, science education in Tanzania faced significant challenges. Declining student interest, poor examination results, and a shortage of qualified teachers were key issues. To address these challenges, interventions such as science innovation programmes and borrowing materials from international sources were implemented. Programmes such as NSTP, SSP, Elimu ya Kufikiri, SSP, and SMP aimed to enhance practical and career-oriented science education.

Educational reforms in Tanzania during this period resulted in notable achievements. Work and education were integrated, manual work was included in the secondary school curriculum, and vocational secondary education was introduced. The establishment of a

curriculum development team and MTUU supported these reforms. Practical activities were successfully integrated into schools and colleges, and practical work assessment was included alongside academic evaluation. Government control over educational institutions increased through nationalization. However, challenges such as language difficulties, limited laboratory resources, and a focus on memorization persisted, hindering the effective implementation of practical education.

Since the 1990s, Tanzania has undertaken various initiatives to enhance science education and ensure that students develop the necessary competencies and skills. These initiatives include projects such as TEAMS, SESS, STIP, and the Education II Project. Their goals were to shift secondary school science education towards inquiry and experimentation, instil the values of the scientific method, and offer professional development for teachers. Although these programmes have positively influenced the quality of science education, the primary challenge is to effectively reorient teachers through both pre-service and in-service training, overcrowded classrooms, a mismatch between education and job market needs, teacher shortages, limited resources, and a tendency to prioritize academic subjects over technical ones, all of which affected the quality of education.

Although various projects, including the ENSCIENCE Project, TESP, STHEP, the retooling programme, the DESMICT Education programme, and the LSTT project, aimed to enhance science education, challenges persisted. The SEDP implemented various strategies to address educational challenges, such as constructing new schools, reducing fees, optimizing teaching resources, expanding distance learning, renovating schools for students with disabilities, enhancing teacher training programmes, aligning the curriculum with job market needs, improving library facilities, and enhancing examination systems. However, despite these initiatives, challenges in science education continued to exist.

Discussion

The implementation of science education in Tanzania and the quality of mathematics education in East Africa face numerous challenges that have significant implications for disparities, employment opportunities, and poverty levels (Sarungi, 2016). These challenges encompass various aspects, such as the neglect of indigenous knowledge, the predominance of a Western perspective in science teaching, inadequate curriculum that fails to establish connections between subjects and daily life, limited knowledge of the outcomes of reform efforts, disparities in academic achievement between urban and rural areas, overcrowded classrooms, lack of resources, and teacher-centered patterns of interaction (Semali & Mehta, 2012; Kajoro, 2016; Tennant & Sarungi, 2016;).To address these multifaceted challenges, comprehensive reform efforts are crucial, which should prioritise the value of cultural contexts, promote practical applications, foster creativity, and address funding issues (Semali & Mehta, 2012). In order to achieve high-quality science and mathematics education, it is essential to harmonize efforts across the region, evaluate teaching methods, provide inclusive and engaging curricula, and invest in teacher training and professional development (Kajoro, 2016; Tennant & Sarungi, 2016).

Teacher training and professional development play a crucial role in improving the quality of mathematics education (Kajoro, 2016). Initiatives such as the SMASSE programme in Kenya and JICA collaborations in Tanzania have demonstrated positive impacts on teachers' classroom practices (Sarungi, 2016). These initiatives are designed to enhance the teaching and learning of mathematics and science in East Africa, with ongoing efforts to improve

mathematics teacher education practices across the region (Tennant & Sarungi, 2016). In the context of science education, external agencies such as UNESCO, UNICEF, and the World Bank have provided financial aid, equipment, books, teachers, experts, and training to support science education in the surveyed countries (Mhaiki, 1986). Collaboration among various stakeholders, including scientists, teachers, government officials, school administrators, curriculum developers, and the national examination council, is crucial for developing a scientifically valid and culturally relevant science curriculum (Mhaiki, 1986).

Although there are challenges in implementing inquiry-based teaching, successful examples have shown its effectiveness. Meta-analysis of empirical studies also supports the use of inquiry in science classrooms. Teacher educators are crucial in preparing student teachers for inquiry-based science teaching by aligning expected student outcomes with psychological consistency, personal goals, and ecological consistency (Semali & Mehta, 2012).

In the context of mathematics education, it is necessary to address the constraints faced by teachers in posing non-routine questions and expecting open-ended answers from students. The article discusses various constraints that affect the learning environment, including the cultural climate, teachers' experience, curriculum demands, and a focus on quantity rather than quality in student learning outcomes. To overcome these challenges, the authors suggest using innovative teaching approaches like metaphorical thinking. They argue that such approaches can improve students' mathematical questioning skills and help tackle the mentioned obstacles (Hendriana et al., 2017). The rapid implementation of education policies in Hong Kong without considering the local context has resulted in dissatisfaction and challenges. According to Poon and Wong (2008) the introduction of Direct Subsidy Scheme schools and "through-train" schools has raised concerns about equity and social stratification. These reforms have generated uncertainty and anxiety among students, parents, and teachers, and the new curriculum and assessment methods have necessitated adjustments in teaching strategies and resources. However, teachers were not adequately prepared for these changes, and the new admissions mechanisms have increased competition and pressure on students to perform well.

Studies have shown the benefits of problem-based learning (PBL) in mathematics (Owusu & Antwi, 2022). Practical work in chemistry has positive impacts on students' conceptual understanding, although challenges such as lack of resources need to be addressed (Iyamuremye et al., 2023; Mukaniyonsenga et al., 2023). Inquiry-based learning improves student interest and attitudes, but effective implementation requires teacher training and resources (Hang & Srisawasdi, 2021). Challenges exist in implementing STEAM education, highlighting the need for teacher professional development. Teacher training, technology integration, and instructional strategies (Lekhu, 2023)are crucial for enhancing teaching competencies (Mamlok-naaman, 2015). Effective science teaching necessitates teacher awareness, self-knowledge, and understanding of teaching methods (Lekhu, 2023).

When it comes to curriculum reforms, it is imperative to strike a balance between incorporating local cultural knowledge and practices with global scientific and mathematical concepts (Semali & Mehta, 2012; Halai & Tennant, 2016). Integrating indigenous knowledge systems into the curriculum can actively engage students and make learning meaningful (Semali & Mehta, 2012). This approach helps students perceive the relevance of science and mathematics in their everyday lives and fosters a sense of ownership and pride in their cultural heritage. Furthermore, the provision of adequate resources such as textbooks, laboratory equipment, and technology is essential for effective science and mathematics

education (Kajoro, 2016; Tennant & Sarungi, 2016). Access to quality resources can enhance students' understanding and practical skills in these subjects (Tennant & Sarungi, 2016). While the 2023 Education and Training Policy place greater emphasis on developing skills that are relevant to the changing job market, such as critical thinking, problem-solving, communication, and digital literacy (URT, 2014)investment in infrastructure and facilities, particularly in rural areas, is necessary to address the disparities between urban and rural education (Halai & Tennant, 2016).

In summary, improving the quality of mathematics and science education in East Africa, including Tanzania, requires comprehensive and coordinated efforts. These efforts should focus on culturally relevant curriculum development, teacher training and professional development, provision of resources, integration of inquiry-based and problem-based learning approaches, and addressing the disparities between urban and rural areas. Collaborative partnerships among stakeholders, including governments, educational institutions, and international organizations, can contribute to the successful implementation of reforms and the promotion of high-quality Science education in the region. For these to be achieved short-, medium- and long-term strategies have to be considered:

Short Term Strategies

1. Tanzania should address the shortage of science teachers and enhance Science education by retaining and recruiting qualified teachers through incentives and contracts for retired educators, ensuring experienced professionals in schools.

2. Expanding the Diploma in Science Education programme and strengthening science teacher education colleges will improve the training of future science teachers, enhancing their capabilities to deliver quality instruction.

3. Promoting exchange programmes with successful education systems can facilitate knowledge sharing and improve science education practices, enabling Tanzania to learn from the experiences of other countries. Additionally, providing necessary science teaching resources in schools, particularly in science-focused institutions, will enhance the quality of science education.

Medium- and Long-Term Strategies

Facilitate the institutions focused on STEM teacher education and training, as well as strengthen science education programmes at universities and teacher colleges. Further improvements are needed, particularly at the universities that produce secondary school science and mathematics teachers. Implementing these strategies would contribute to the production of well-trained science teachers and educators, leading to an overall improvement in science education throughout Tanzania.

Conclusion

In conclusion, tackling the shortage and quality of science teachers in Tanzania necessitates a comprehensive approach. By allocating responsibilities among institutions, enhancing training facilities, establishing specialized programmes for laboratory technicians, creating a favourable career trajectory, and implementing long-term in-service education initiatives, significant progress can be made. Strengthening institutions and implementing these

strategies will not only enhance Science education but also foster the growth of a skilled and capable STEM workforce in Tanzania.

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