International Journal of Humanities Social Sciences and Education (IJHSSE)
Volume 12, Issue 4, April 2025, PP 9-16
ISSN 2349-0373 (Print) & ISSN 2349-0381 (Online)
https://doi.org/10.20431/2349-0381.12040002
www.arcjournals.org

Insights into the Implementation of Stem Education: A Study of a Selected Stem School in Lusaka District

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Abstract: *The introduction of the Science, Technology, Engineering, and Mathematics (STEM) education programme in Zambia is a response to the need for the provision of quality science and technology education for individual and national development and in line with the Zambia education competence-based curriculum framework of 2023, to produce a learner who is independent, creative, productive, a critical and analytical thinker who relates his/her thinking to solving real-life problems. However, the STEM education programme in Zambia could not continue as intended, and its implementation was suddenly discontinued. This study sought to establish insights into the implementation of STEM education and propose implementation frameworks for improved and sustainable STEM education implementation in Zambian secondary schools. The study used a case study research design and purposive sampling to sample respondents at the selected STEM secondary school in Lusaka. Semi-structured interview guides and document reviews were used to collect data. Data were analysed using thematic analysis. The study found that all the respondents had an understanding of what STEM education is all about. Further, the study found that STEM education should be implemented as an approach to teaching and learning through project-based learning in order to promote analytical thinking and creativity in the learners. Based on these findings, this study recommends that JETS be incorporated into the national curriculum as a tentative STEM education implementation framework.*

Keywords: *STEM, Implementation, Curriculum, Framework, JETS*

1. INTRODUCTION

STEM education refers to the educational innovation approach based on educating learners in the four disciplines of science, technology, engineering and mathematics in an interdisciplinary and applied approach to foster analytical and critical thinking (Bybee, 2010). White (2014) attested that STEM education emerged as an innovative educational approach aimed at transforming education for the purpose of enhancing real-life problem-solving skills. Hu, Li, Geng, and Zhao (2024) add that STEM education is an approach to learning that promotes collaboration, innovation, creativity, and critical thinking in the learners.

The Government of the Republic of Zambia aims at diversifying its economy to become a knowledge-based economy in which science and technology education play a critical role in achieving Zambia's economic and development goals, such as making Zambia a middle-income nation by 2030 (National Long-Term Vision 2030) and a developed country by 2063 (Agenda 2063), as stipulated in the Seventh National Development Plan (GRZ, 2017). In addition, Zambia seeks to enhance its regional and global competitiveness by developing a skilled workforce in the field of STEM in order to overcome the high technological industry challenges (Magasu, Mutale & Gondwe, 2022). To achieve these economic and developmental milestones, improved and sustainable STEM education implementation becomes critical.

To respond to the needs for the provision of quality science and technology education for sustainable development and job creation among the large population of youths, Zambia looked into the implementation of STEM education as a transformative education initiative to transform science education (Yangailo, 2024). The Zambian government has in the past introduced policies that support STEM education, such as the Seventh National Development Plan and the adoption of the Higher

Education Policy of 2019, which emphasise economic diversification, job creation, enhanced human capital, and skills development through quality education (GRZ, 2017). In addition, other efforts towards improving STEM education for sustainable economic development in Zambia have been seen through the establishment of the Ministry of Technology and Science, the National Science Centre (NSC), and the National Science and Technology Council (NSTC) as legal frameworks with a mandate to oversee the national science and innovations landscape in Zambia (Sililo, 2017).

According to the Ministry of General Education (MoGE, 2020), the implementation of STEM education in Zambia started in 2020, with fifteen out of the fifty-two targeted piloting STEM secondary schools, which were formerly called National Technical secondary schools. To this effect, a transitional STEM curriculum was jointly developed by the Curriculum Development Centre (CDC) and the National Science Centre (NSC). STEM education curriculum was executed at two secondary school entry grade levels (grade eight and grade ten). The curriculum was characterised by a major shift from the mainstream positivist teaching and learning approaches to a constructivist approach in which learners were to take the central stage in the learning process (Mwale, Moonga & Banda, 2020).

The main objective of STEM education implementation is to produce a learner who is a critical, creative, and analytical thinker who relates his/her thinking to real-life situations and is a problem solver (MoGE, 2018).

STEM education in Zambia was welcomed by several education stakeholders, including parents, learners, and teachers, because of its anticipated benefits and transformative ideas imbedded in the programme. However, despite the anticipated progressive benefits of STEM education and its implementation, on 7 May 2021, the Ministry of General Education (MoGE), through the Office of the Permanent Secretary at the time, announced a sudden stop to the STEM transitional curriculum implementation, indicating that the curriculum's weaknesses outweighed its strengths and that the learners following the curriculum would only be assessed using the mainstream 2013 national curriculum until further guidance on STEM education was to be given.

While STEM education is critical for Zambia's economic diversification and global competitiveness, its implementation in secondary schools remains a concern. Despite deliberate efforts such as the introduction of outcome-based policies and legal frameworks to enhance STEM education, challenges including inadequate resources, inadequate teacher professional development in STEM, and lack of support systems persist in the implementation of STEM education (Magasu, Mutale & Gondwe, 2022). In Lusaka district particularly, there is limited research on the implementation of STEM education, leading to limited understanding of the progressive strategies and best practices in STEM education. Thus, this study sought to establish insights in the implementation of STEM education at a selected STEM school in Lusaka district, identifying strengths, weaknesses, and opportunities to inform evidence-based decision-making and improved STEM education outcomes in the future.

2. METHODOLOGY

The study adopted a qualitative approach to generate data where the experiences, views and opinions of teachers and their administrators in STEM were sought. The study used a case study research design. A homogenous purposive sampling technique was used to sample teachers, heads of departments, and head teacher at the selected STEM school in Lusaka district. The instruments that were used to collect data were the interview guides and document reviews. The sample size of the study included nine (9) teachers who implemented STEM education at the selected STEM school, three (3) heads of departments, and one (1) head teacher. Ethical clearance was sought from the University of Zambia research ethics committee, and permission to collect data was sought from the office of the District Education Board Secretary (DEBS). Confidentiality and anonymity were ensured by not revealing the respondents' names and personal details. Collected data were analysed using thematic analysis.

3. THEORETICAL FRAMEWORK

This study was guided by the constructivism learning theory. The theory suggests that learning is a constructive process where learners build new ideas and understanding based on the already existing knowledge and experiences (Fosnot, 2013). Constructivism learning theory is appropriate to underpin this study because of its emphasis on the assumption that knowledge is constructed. According to Amineh and Asl (2015), constructivism theorists believe that learners actively construct their own knowledge and understanding of the world around them through experiences, interactions, and

collaborations. Constructivism theorists also believe that knowledge is socially constructed and view the school as a social environment where learners are able to interact, collaborate, and work together with their peers in constructing meaning (Hug & Wurdinger, 2007).

Contextualizing the constructivism theory of learning in this study, it is clear that STEM education has become a widely recognised programme because of its potential to produce a holistic learner capable of applying thought patterns from all the four disciplines of STEM to solve real-life problems that need multi-disciplinary solutions. The special feature within the constructivism learning theory that supports STEM education is the learner-centred approach that encourages experiential teaching and learning, collaborative learning, building problem-solving, and critical thinking skills. STEM education relates well with the principles of constructivism learning theory as it focuses on developing a learner who is analytical, innovative, creative, and capable of applying acquired knowledge and scientific thoughts to solve problems using the concepts from all four disciplines of STEM (Sakala & Banda, 2020).

Achieving STEM education implementation goals depends on the teachers' competence to put into practice the principles embedded in constructivism theory for improved and sustainable STEM education implementation. Therefore, the philosophy of constructivism learning theory is relevant and worthy of adopting to underpin this study on STEM education for achieving the intended STEM education outcomes in Zambia.

4. Results and Discussion

This study sought to establish insights into the implementation of STEM education with a primary focus on the experiences teachers had with the STEM education programme at the time it was implemented at the selected STEM school in Lusaka, and their opinions towards improved STEM education implementation in Zambian schools in the future. To achieve this purpose, the following were investigated:

a. Teachers' understanding of STEM education at the selected STEM school in Lusaka district.
b. Teaching methods teachers were using to teach STEM at the selected STEM school in Lusaka district.
c. Tentative STEM education implementation framework(s) for improved STEM education implementation in Zambian schools.

4.1. Teachers' Understanding of STEM Education

The results showed that all the respondents had an understanding of what STEM education was all about. The respondents understood STEM education as an educational approach that enhances the link between theory and application of the scientific knowledge in solving real-life problems. They also understood STEM education as a learner-centred educational approach that promotes critical and analytical thinking skills in the learners. When the respondents were asked to give their understanding of STEM education, the following were some of their responses:

*For me, STEM is an approach in education that bridges the gap between the application and abstract teaching of science and mathematics subjects. STEM focuses on making learners appreciate what they learn in class, in relation to real-life situations (*Tm2*)*

"STEM education is a learner-centred approach where learners construct their own knowledge with the guidance of the teacher. Behind STEM education, we aim at producing a learner who is a critical thinker" (Tp1)

STEM education is an approach in science education that puts the learners at the centre of learning by allowing learners to research, search for information, and find solutions to problems on their own. It is also an approach where teachers design open-ended trigger situations and allow learners to design solutions to the problems on their own, of course with the guidance of the teacher (Tb1).

From the responses given on teachers' understanding of STEM education, it was clear that STEM education was understood as a transformative education approach that focuses on producing learners who are creative, analytical, and critical thinkers who can apply the knowledge and skills from the four disciplines of STEM to solve problems. The findings are in accordance with Mwale, Moonga and Banda (2020) who contend that the primary objective of STEM education programme was to produce a learner who is a critical and analytical thinker who relates his/her thinking to real-life situations and is a problem solver. According to Rifandi and

Rahmi (2019), the purpose of implementing STEM education is to find solutions to the challenges in the 21st Century, where learners are to be skilled, competitive, and ready to work according to their preferred fields.

In addition, teachers understood STEM education as a constructivist education approach that uses concepts of technology and engineering to link the theory and application of scientific thinking to solving real-life problems that many societies face in the 21st century. The findings align with the constructivism learning theory that emphasises on the learner-centred approach and encourages the shift of education from the teacher-centred approach, where learners are passive consumers of knowledge, to a more transactional education approach where learners are active participants in the construction of knowledge (Brown et al., 2011). Therefore, successful STEM education implementation in secondary schools requires that teachers understand the programme in terms of its purpose, outcomes, and relevance. Teachers' understanding of STEM education is of crucial importance as it enhances the confidence of teachers to plan learning experiences that are in line with the prescribed STEM education outcomes, such as developing a critical and innovative mind-set in the learners (MoGE, 2020).

This study showed that teachers understood STEM education as an educational innovation with the potential to transform the Zambian education sector from a system of generating scientific knowledge to a system of applying scientific knowledge and engineering in solving real-life problems such as the crisis of climate change, unemployment, value addition, and agricultural productivity, which might have affected the economic development of the country (MoGE, 2020). In addition, STEM education was introduced in Zambia following the review of the performance and contribution of the National Technical Secondary Schools to real-life problem-solving and national development (MoGE, 2018).

Therefore, for Zambia to achieve its economic development aspirations, regional and global competitiveness through the education sector, teachers' understanding of STEM education and its relevance becomes critical for the successful implementation of STEM education in schools.

4.2. Teaching Methods Teachers Were Using to Teach STEM

Successful STEM education implementation lies in the teachers' competence to select and use appropriate teaching methods to deliver the curriculum intentions to the learners. In addressing research number two, which sought to establish the teaching methods that teachers were using to teach STEM at the selected school, the results showed that teachers used learner-centred teaching methods that included problem-based teaching and learning, experiments, small group discussions, practical scenarios, and research. When the respondents were asked to give the teaching methods they were using to teach STEM, the following were some of the responses:

"I used the problem-based teaching method as my best method, where learners were allowed to find solutions to open-ended problems on their own." (Tp1)

"With STEM education, we have tried to connect what learners learn in theory with the practical through experiments [practical activities] to enhance their understanding of science concepts." (Tc1)

"We allowed learners to do a lot of research, and through research, we realised that indeed the learners we have in schools are great researchers; when we teach in a traditional way, we actually limit their potential to think critically." (Tm2)

From the teaching methods that were identified in this study, it was clear that teaching methods are critical components of STEM education implementation in the sense that STEM education is an innovative educational approach that emphasises the learner-centred teaching methods embedded in the constructivism learning theory (Diana & Sukma, 2021). The findings are in alignment with the view of Hug and Wurdinger (2007) who noted that constructivist teachers design instructions such as problem-based learning that engage learners in active learning experiences that foster analytical and critical-thinking skills.

According to Akiri, Tor and Dori (2021), learner-centred teaching methods such as problem-based teaching, experimentation, project-based learning, and research have been recognised as appropriate and effective for the successful implementation of STEM education because of their potential to create a teaching and learning experience that is interactive and aimed at solving real-life challenges such as climate change that require multidisciplinary solutions.

The teaching methods that teachers were using to teach STEM at the selected school were in line with Zambian government's effort to implement STEM education aimed at producing learners who are self-motivated,

creative, confident and productive individuals, with values, skills, and knowledge to enable them and their society survive (Magasu, Mutale & Gondwe, 2022). Therefore, the use of inquiry teaching methods such as problem-based learning and project-based learning by teachers at the selected school was an indication that there was conformity to the teaching methods that were recommended in the STEM education transitional curriculum (MoGE, 2020).

However, some of the respondents stated that they used question and answer and discussion as teaching methods to teach STEM. The implication is that teaching and learning experiences may not have been planned in accordance with the appropriate teaching methods to successfully deliver STEM lessons, as question and answer and discussion are not, in principle, teaching methods. This was an indication that there is a need for professional training among teachers in STEM education to enhance their capacity and competence to distinguish between teaching methods and teaching strategies.

4.3. Tentative STEM Education Implementation Framework(s) for Improved STEM Education in Zambian Schools in the Future

For the STEM education programme to be implemented successfully in Zambian schools, it is necessary that its vision, curriculum, and context are clearly understood and supported by various stakeholders. Literature indicates that for every education reform to be implemented successfully, it must be understood by all key stakeholders in terms of its relevance and value (Chiu, Price & Ovrahim, 2015). Thus, successful implementation of STEM education in Zambian schools requires that a clear framework for implementation in line with the national economic development aspiration is put in place.

The findings of this study indicated that STEM education in Zambian schools should be implemented as a teaching approach where the teaching of every subject would incorporate technology and engineering to enhance analytical thinking and problem-solving skills in the learners. When the respondents were asked to give their views of what they perceived STEM education implementation would be like, the following were some of the responses:

STEM should be implemented as a teaching approach to help link the abstract teaching of mathematics and science to the world of application. Technology cannot be taught alone but can be incorporated in other subjects, and that is what STEM is all about. (Tm2)

For me, I still go back to the teaching methods being key in STEM education implementation. Each topic taught in science should aim at solving a problem that society is facing (relevance and value of education), and topics should be listed in such a way that they solve environmental, climate or other problems. Learners must be able to produce a product after learning some concepts (application) in STEM. (Tp1)

I think STEM education in Zambia can best be implemented through strengthening JETS projects. Every time we have a JETS fair, we see people from other countries come and get some ideas from our project presentations. When they go back home their governments implement those ideas, and they produce products that later come back, and we buy them. (Tp1)

Regarding the format that STEM education implementation should take in line with the national developmental agenda, the study suggested that Junior Engineers, Technicians, and Scientists (JETS) projects be formalised and incorporated into the national curriculum as a way of engaging schools and learners in collaborations and positively contributing to the national economic development aspirations through the education sector. Incorporating JETS projects into the national curriculum would improve the implementation of the STEM education programme and strengthen the application of the scientific knowledge and skills needed to address various economic challenges that local communities face in Zambia. It is from this view that Zambia focused on reviewing its school curriculum, making it knowledge, skills, and values (KSV) compliant, and STEM education becomes a pillar to strengthen Zambia's competitiveness at both regional and global levels (Mwale, Moonga & Banda, 2020).

Therefore, the study proposed a tentative STEM education implementation framework that strengthens JETS projects in Zambian schools to be appropriate for improved and sustainable STEM education implementation. The proposed tentative implementation framework is in line with the objectives of STEM education to produce analytical, innovative, productive, and self-directed learners who are able to apply their thinking in solving problems (Mwale, Moonga & Banda, 2020). This implies that learners would engage in

school projects that are aimed at producing tangible products using the concepts in STEM, hence contributing to the sustainable individual and national economic development.

The proposed tentative implementation framework is also in line with the constructivism theory of learning that underpinned this study based on the assumptions that an education system of relevance engages learners in learning experiences that allow them to construct knowledge through collaborations and interaction with the real world (Diana & Sukma, 2021).

In context, as Zambia strives to provide an education that should enhance quality and productivity in disciplines such as agriculture, mines, technology, and tourism and also the application of scientific skills to solve social, economic, and environmental problems, context-based JETS projects incorporated into STEM education would form a progressive implementation approach for improved and responsive STEM education.

Further, project-based education such as JETS enhances learners' conceptual understanding as learners engage in active learning experiences such as scientific inquiry, discovery learning, experiments, and research (Khotimah, Adnan & Murtiyasa, 2021). From the literature reviewed, it was observed that most STEM implementation frameworks, such as the project-based learning (PjBL) framework in the case of Indonesia, emphasised projects to be key in the implementation of STEM education because of the interplay among scientific knowledge acquisition, application of scientific and engineering skills, and production of tangible products.

In addition, learning from other education systems through literature review, it was observed that transformative STEM education implementation frameworks that embrace project-based learning are widely adopted, as can be noted in the case of Indonesia (Permanasari, Rubini & Nugroho, 2021). It is from this perspective that this study proposed the incorporation of JETS projects into STEM education as a tentative implementation framework to improve the implementation of STEM education in line with the national developmental agenda. This study noted that without JETS projects being supported and incorporated into STEM education to form the basis for improved and sustainable STEM education implementation in Zambia, STEM education will remain theoretical and only on paper.

5. CONCLUSION

The study concluded that teachers at the selected STEM school understood STEM education as an innovative and interdisciplinary educational approach that uses technology and engineering to enhance creative and analytical skills in the learners, transforming them to become innovative, productive, responsible, and problem solvers in their respective communities. The implication of this understating of STEM education implementation is that teachers would plan learning experiences in line with the stipulated STEM education objectives in the Zambian context. The study further concluded that the teaching methods that teachers were using in teaching STEM were in conformity with the teaching methods recommended in STEM curriculum guidelines for implementation. However, some teachers had a challenge distinguishing teaching methods from strategies. The implication is that lessons would not be planned and delivered in line with STEM education curriculum intentions, hence impeding the achievement of STEM education goals. The study proposed that JETS projects are supported and incorporated into the national curriculum of 2013 as a tentative STEM education implementation framework for improved and sustainable STEM education in Zambian schools. For further research on this topic, studies are encouraged to test the proposed tentative STEM education implementation framework for effectiveness on a large scale involving all secondary schools in Zambia.

6. RECOMMENDATIONS

In view of this study, the following recommendations were made:

1. STEM education should be implemented in the form of JETS projects imbedded in the mainstream 2013 curriculum as a tentative STEM education implementation framework for improved and sustainable STEM education.

2. The Ministry of General Education should create more avenues and access for collaboration and partnerships with local industries so that career pathways for the needed skills are clear to the learners while they are at secondary school.

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Citation: *Haamasama Christopher et.al."Insights into the Implementation of Stem Education: A Study of a Selected Stem School in Lusaka District". International Journal of Humanities Social Sciences and Education (IJHSSE), vol 12, no. 4, 2025, pp. 9-16. DOI: https://doi.org/10.20431/2349- 0381.12040002.*

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