INSIGHTS INTO THE IMPLEMENTATION OF STEM EDUCATION: A STUDY OF A SELECTED STEM SCHOOL IN LUSAKA DISTRICT

BY

CHRISTOPHER HAAMASAMA

SUPERVISOR: DR KABUNGA NACHIYUNDE

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DECLARATION

I, Christopher Haamasama, do hereby declare that this dissertation is my own work. Any published or unpublished work or materials of other persons used have been acknowledged. This work has not previously been submitted to this or any other university for similar or any other purposes.

Signed …… Date ……

CERTIFICATE OF APPROVAL

This dissertation by Christopher Haamasama is approved as fulfilling the requirements for the award of the Master of Education in Science Education (M.Ed.) by the University of Zambia.

Name of Examiner	Signature	Date
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DEDICATION

This work is dedicated to my father Dyson Haamasama and my mother Ebester Mwiinga for their unfailing support throughout my academic endeavours and throughout this study.

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ABSTRACT

The purpose of this study was establish insights into the implementation of STEM education at the selected STEM secondary school with a focus on the experiences that teachers had with its implementation, and the views they held regarding the future implementation of STEM education. This was achieved first by establishing teachers' understanding of STEM education, then establishing lived experiences teachers had with STEM education implementation by establishing the teaching methods they were using in teach STEM during the time it was implemented. This was based on finding out how the interdisciplinary nature of STEM education was achieved through various teaching methods.

The study was qualitative and used a case study research design. Data were collected using semi-structured interview guides and document reviews. The study population was all teachers of STEM and administrators at the selected STEM secondary school. The sample size of thirteen respondents comprised nine STEM teachers, three heads of departments, and one administrator. The respondents were selected using homogenous purposive sampling. Data was analysed thematically.

The study revealed that teachers viewed STEM education as a learner-centred education approach that uses concepts of technology and engineering to link what is theory and application of scientific skills to solve real-life problems. Some respondents viewed STEM education as an education approach to producing a learner who is technology-oriented, analytical and a creative thinker. The study also revealed that the teaching methods teachers were using in teaching STEM included problem-based teaching, small group discussions, inquiry, scenarios, and research. Further, the study showed that implementation of STEM education at the selected STEM secondary school faced some challenges that included inadequate teaching and learning resources, inadequate training for teachers in STEM education to handle STEM with expected competences, lesson planning being involving and time-consuming among other challenges. The study concluded that STEM education is a progressive programme with potential to produce learners who are analytical and productive, who are able to relate their thinking to solving real-life problem. The study further proposed a tentative STEM education implementation framework in which JETS projects are to be integrated into the national curriculum of 2013 for improved STEM implementation.

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LIST OF ACRONYMS

STEM - Science, Technology, Engineering and Mathematics

PjBL - Project-Based Learning

PBL - Problem-Based Learning

DEBS - District Education Board Secretary

UR - University of Rwanda

KIST - Kigali Institute of Science and Technology

SIDA - Swedish International Development Cooperation Agency

NSC - National Science Centre

CDC - Curriculum Development Centre

ECZ - Examinations Council of Zambia

UNZA - The University of Zambia

MoGE - Ministry of General Education

ICT - Information and Communication Technology

JETS - Junior Engineers, Technicians and Scientists

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter contains the background information to the study, statement of the problem, purpose of the study, research objectives, research questions, significance of the study, delimitation of the study, theoretical framework and chapter summary.

1.1 Background Information

Education is considered one of the key elements of development, either as a way of developing human capacity, increasing the skilled workforce for the labour market, as a matter of individual development, developing capability, or empowerment (Alam, 2009). Education plays a critical role in the lives of individuals, as its main purpose is to provide individuals in the community and learning institutions with relevant knowledge, skills, ideas, competencies, and values to lead fulfilling, productive, innovative, and satisfying lives. Hence, every government has the responsibility to provide an education of good quality to its people in all institutions of learning (Okeke, 2007). One of the ways in which most education systems have been reformed to address 21st century challenges is through the implementation of Science, Technology, Engineering and Mathematics (STEM) education (Alam, 2009).

STEM education refers to an education approach based on educating learners in four disciplines of Science, Technology, Engineering and Mathematics in an interdisciplinary and applied approach, where the teaching and learning process of any of the four disciplines depends on the expertise of the other three disciplines (Bybee, 2010). Barakos, Lujan, and Strang (2012) note that STEM education is an interdisciplinary approach for enhancing scientific knowledge construction, skill development and application in solving problems.

White (2014) attested that STEM education emerged as an innovative educational approach aimed at transforming education for the purpose of linking science education to real-life situations and the application of the acquired knowledge and skills in solving problems. Haryani, Coben, Pleasants and Fetters (2021) added that, in a world faced with

environmental, technological, and socio-economic challenges, STEM education should equip learners with skills to confront such challenges with competencies.

Having given the background on the importance of STEM education, the Government of the Republic of Zambia has among other developmental agenda strove to provide equal educational opportunities for all citizens at all levels of education as indicated in the Educating Our Future policy document of 1996 (Masaiti, 2018). Improved science and technology education in Zambia, has in the recent past attracted tremendous efforts through education legal frameworks such as the creation of the Ministry of Technology and Science, National Science Centre and National Science and Technology Council, because of its role in both individual and national economic development. As stipulated in the National long-term plan (Vision 2030), Zambia has embarked on a multi-dimensional transformational agenda in which science and technology education is critical in making Zambia a middle-income nation by 2030 (National Long-Term Vision 2030) and a developed country by 2063 (GRZ, 2017).

To respond to the need for the provision of quality science and technology education for sustainable economic development and in response to global challenges, the Zambian government identified STEM education as one of the areas that can be strengthened to help the nation transition from a natural resource-based economy to a knowledge- and information-based economy that is fully dynamic, competitive and robust in stature. This is in line with what the United Nations Conference on Trade and Development (UNCTAD) (2022) recommended: "this situation is unlikely to change unless Zambia embarks on a broader and more forceful process of technological upgrading, because economic diversification is heavily dependent on science, technology, and innovation." (p.6). Thus STEM education implementation in Zambia, in line with the economic diversification goals is critical.

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 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. The operationalisation of the transitional 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. The objective of STEM

education is 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 (Mwale, Moonga & Banda, 2020).

STEM education was welcomed by many education stakeholders, which led to the implementation of its transitional curriculum at grade eight and ten entry levels in the fifteen selected STEM secondary schools, in 2020 (MoGE, 2018). In addition, teachers in these schools were given a short training on how to teach STEM, in which they were expected to teach the four disciplines of science, technology, engineering and mathematics using an interdisciplinary approach. Unfortunately, on 7 May 2021, one and half years into the implementation process, 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 be assessed using the mainstream 2013 national curriculum until further guidance on STEM education was to be given (Magasu, Mutale & Gondwe, 2022).

Apparently, implementation of STEM education in Zambian secondary schools face several challenges including inadequate teaching and learning resources, teacher training, school leadership support systems and infrastructure (Nadelson & Seifert, 2017). Despite efforts to implement STEM education, such as creation of educational legal frameworks such National Science centre and National Science and Technology Council with mandate to oversee the the national science and innovations landscape in Zambia, there is limited research in the implementation of STEM education in the schools particularly in Lusaka District. Therefore, there is need for research around STEM education implementation aimed at informing policy-decisions and practices, understanding and identifying of opportunities for improved STEM education implementation. It is from this background that this study sought to explore insights into the implementation of STEM education at the selected STEM secondary school in Lusaka District, focusing on teachers' understanding, experience, and views for improved STEM education implementation in future.

1.2 Statement of the Problem

Although STEM education has its origins in the early 1990s in the United States of America, in Zambia, its implementation began, in 2020 and was executed at two secondary school entry levels, grade eight and grade ten. However, on 7 May 2021, the Ministry of General Education through the Office of the Permanent Secretary of Technical Services, issued a

circular to immediately discontinue STEM education curriculum implementation, indicating that its weaknesses had outweighed its strengths (Magasu, Mutale & Gondwe, 2022).

Despite STEM education being critical for Zambia's economic development and global competitiveness, its implementation could not continue as intended. Stakeholders attributed one of the weaknesses of STEM education implementation to the separation among the curriculum development, teaching, and assessment bodies. The coordination among the Curriculum Development Centre (CDC), schools, and Examinations Council of Zambia (ECZ) regarding STEM education implementation may not have been adequate, and this would have led to difficulties in conducting STEM national examinations (Personal Communication, 2022).

In spite of efforts to improve STEM education implementation in schools, it appears there is a lack of research on STEM education implementation in secondary school specifically in Lusaka, leading to a limited understanding of effective strategies and best practices in the implementation of STEM education. Therefore, this study sought to establish the insights into the implementation of STEM education at the selected STEM secondary school in Lusaka district, establishing teachers' understanding of STEM education, teaching methods used for teaching STEM and opportunities for improved STEM education implementation in future.

1.3 Purpose of the Study

The purpose of the study was to establish insights into the implementation of STEM education at the selected STEM secondary school in Lusaka district.

1.4 Research Objectives

The objectives of this study were as follows:

(i) To establish the teachers' understanding of STEM education at the selected STEM school.

(ii) To explore the teaching methods teachers used in teaching STEM at the selected STEM school.

(iii) To establish tentative implementation framework(s) for the sustainable implementation of STEM education in Zambia.

1.5 Research Questions

The study was guided by the following research questions:

(i) What are the teachers' understanding of STEM education at the selected STEM school?

(ii) What teaching methods did teachers use in teaching of STEM at the selected STEM school?

(iii) What tentative STEM implementation framework(s) could be adopted for the sustainable implementation of STEM education in Zambia?

1.6 Significance of the Study

After evidence-based data are collected on the previous STEM education and teachers' views for the enhanced STEM education implementation in Zambia, the study is anticipated to benefit science teacher trainers [universities] by providing them with information on the expectations of the teachers of STEM subjects, in terms of pedagogical Content Knowledge (PCK). This would in turn help in improving STEM education implementation and practices at classroom level.

The study was also anticipated to provide feedback information to the Ministry of General Education, the National Science Centre, the Curriculum Development Centre (CDC), and the Examinations Council of Zambia (ECZ) on how STEM education was implemented in schools in terms of success, challenges and measures needed to be taken for improvement in STEM implementation in the future. This study is also significant in the sense that STEM education in Zambia is still in its early stages, hence, the appropriate time to conduct this study. The study is also likely to help other researchers in the future to add to the pool of existing knowledge on STEM education and its effective implementation frameworks in the context of the Zambian education system.

1.7 Delimitation of the study

The following were the delimitations of this study:

- Due to the large number of potential participants in the study population, the sample of who was to participate in the study only focused on teachers teaching STEM subjects at senior secondary school level and their administrators, respectively.
- The study did not intend to investigate the reasons why STEM education implementation failed to continue as intended, it was limited to the understanding,

experience and views for improvements, teachers and their administrators had with STEM education implementation at the selected STEM secondary school in Lusaka.

1.8 Theoretical Framework

This study was guided by constructivism learning theory. Constructivism learning theory is an educational theory that emphasises the active role of the learners in building their own understanding (Fosnot, 2013). It suggests that learning is an active and constructive process where learners build new ideas based on their existing knowledge and experiences. Constructivism learning theory is appropriate for this study because of its emphasis on the notion that knowledge is actually constructed. According to Amineh and Asl (2015), constructivism theorists believe that individuals construct their own knowledge and understanding of the world around them through their experiences, interactions, and reflection. Thus, educators need to understand that learners come to class with some conceptions already existing and that meaningful teaching takes place through creating learning experiences that build new knowledge on already existing knowledge.

The other key notion suggested by the constructivism learning theory is that learning is an active process in which learners are active participants rather than passive, in the construction of knowledge. Amineh and Asl (2015) argued that learning is an active process in which experience plays an important role in understanding and grasping the meaning or concepts. Thus, this assumption emphasises that learners go beyond passive reception of information and engage in learning activities that promote critical thinking, conceptual understanding, and problem-solving skills (Fosnot, 2013).

Constructivism theorists also believe that knowledge is socially constructed and view the school as a social environment that cannot be separated from the learners' learning process, as the school forms a social community where learners are able to interact, collaborate, and work together with their peers in constructing meaning (Hug & Wurdinger, 2007).

The other principle of constructivism learning theory is the emphasis on the holistic development of the learner. Holistic development of a learner within the constructivism learning theory presents the idea that learning is a comprehensive process that involves the integration of various cognitive and social domains of the learner (Fosnot, 2013). This involves not only acquiring new knowledge, but also recognising the existing mental structures needed to incorporate the new knowledge.

Therefore, it is appropriate that constructivism learning theory and the principles embedded in it underpin this study on STEM education, as most principles within constructivism, such as knowledge construction, active engagement of the learners in the learning process, and holistic development of the learner, resonate with the principles behind STEM education in that both constructivism and STEM education emphasize learner-centred teaching. In addition, STEM education emerged in schools to transform education from the traditional approach where the teacher is at the centre of knowledge construction to a more transactional approach that involves both the teacher as the facilitator and the learners as the active participants. According to Diana and Sukma (2021), the education approaches that encourages learners to construct their own knowledge through active learning activities, have become a centre of discussion in educations circles in the 21st century.

As an innovative educational approach underpinned by constructivism in this context, STEM education has become a widely accepted programme in many education systems because of emphasis on producing a holistic learner capable of applying thought patterns from all the four disciplines of STEM to solve real-life problems. Thus, the special feature in 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 notions in constructivism learning theory as it focuses on developing an individual who is analytical, innovative, creative, and capable of applying acquired knowledge and scientific thoughts to solve problems that require multidisciplinary solutions, from all the four disciplines of science, technology, engineering, and mathematics (Sakala & Banda, 2020).

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

1.9 Chapter Summary

Chapter one presented the background, statement of the problem, purpose of the study, research objectives, and research questions, significance of the study, delimitation of the study and theoretical framework.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Overview

Literature review refers to the written materials that a researcher has consulted to understand and investigate the research problem. Thus, in this chapter, the literature that was reviewed in relation to the study is presented. The literature was identified through reading of journal articles, policy documents and books that are related to the study. Literature is organised and presented under the following headings, teachers' understanding of STEM education, perspectives and implementation approaches of STEM education, teacher professional development for STEM education, technology integration in the implementation of STEM education, partnerships in the implementation of STEM education, and future directions for STEM education. The chapter concludes with a section on the knowledge gap identified in the literature reviewed.

2.1 Teachers' Understanding of STEM Education

Teachers' understanding of STEM education entails that the planning and implementation of STEM education in the classroom would be in line with the STEM curriculum intentions. A study by Jamal, Ibrahim, Surif, Suhairom, Abdullah and Jumaat (2017) that focused on the understanding of STEM education among chemistry teachers in Malaysia revealed that the majority of the chemistry teachers viewed STEM education as the integration of the four disciplines of science, technology, engineering and mathematics which involves the application of the concepts from the four disciplines of STEM to solve real-life problems. However, the study also indicated that there were some teachers who did not have an understanding of STEM education because they were not sure of the purpose of STEM education and they only knew about STEM education through the internet. Therefore, lack of understanding of STEM education by some teachers affected how they implemented STEM education in their classroom.

A study by Kececi (2023) was conducted to establish pre-service science teacher's understanding of STEM education. The study showed that there was no single definition of STEM education that pre-service science teachers agreed on. In addition, pre-service science teachers had challenges of teaching STEM in an interdisciplinary approach due to their differences in the understanding of STEM education (Kececi, 2023).

A study by Permanasari, Rubini and Nugroho (2021) in Indonesia was conducted to determine the extent to which science teachers in secondary schools understand and interpret STEM education. The study indicated that STEM education was well understood by secondary school science teachers. They interpreted STEM education as an education approach that integrates technology and engineering in the teaching of science and mathematics and focuses on the application of the knowledge from the four disciplines of STEM in real-life problem-solving. According to Permanasari, Rubini and Nugroho (2021), most of the science teachers showed the same levels of understanding towards STEM education. However, the study showed that not many teachers applied STEM teaching approaches in the classroom. Therefore, from the literature reviewed, it is clear that majority of teachers have an understanding of STEM education and believe that STEM education has the potential to foster analytical and critical thinking in the learners. It is also clear that the implementation of STEM education practices in the classroom is dependent upon the teachers' understanding and interpretation of STEM education (Jamal et al., 2017).

2.2 Teaching Methods in the Implementation of STEM Education

One of the key components of STEM education implementation at classroom level is the planning of appropriate teaching methods to be used in achieving the desirable STEM education outcomes. This means that teachers should understand and select effective teaching methods that are in line with STEM education curriculum intentions. According to MoGE (2020), effective teaching methods involve continuous engagement, improvement of interpersonal skills and connection on how to address real-life challenges in line with desirable intentions of STEM education. The implication for understanding and selecting appropriate teaching methods in STEM education is that, teaching and learning activities would be planned in such a way that learning would progress from inquisitiveness into analytical thinking hence, achieving bloom's higher levels of knowledge acquisition which are consistent with the 21st Century proficiencies (MoGE, 2020).

According to MoGE (2020), the recommended teaching methods for effective implementation of STEM education include among others; inquiry teaching methods, problem-based learning (Problem-solving), mastery learning, experimental learning, cooperative learning and field work. According to Zendler, Seitz and Klaudt (2018), problem-based learning, project work and inquiry are the highly-rated teaching methods in STEM education. In addition, employing these teaching methodologies would enhance

acquisition of skills and values, and creation of the productive learner through critical thinking, creativity and analysis which are 21st Century skills. The understanding of the teaching methods to be used by teachers in STEM education has an influence on how the teaching and learning experiences would be planned and executed.

A study conducted by the Ministry of General Education (MoGE, 2020) on the assessment of STEM education implementation in Zambia revealed that teachers understood the importance of the teaching methods in the delivery of lessons across all the STEM subjects and indicated the methods in the rationale section of the lesson plans. Some of the teaching methods that were indicated on the lesson plans included; discovery, problem-based learning, question and answer, experimentation, inquiry, discussion, group work among others. Additionally, the study revealed that, discussion which is not primarily a method in principle was the most prevalent teaching method planned to be used across all the STEM subjects. Therefore, it is perceptible that teachers had a challenge to distinguish what exactly a teaching methodology is from a strategy. This is so because definitely group work, discussion and question and answer are not teaching methods.

In addition, a study by Ring (2019) in Minnesota that focused on the pedagogy for teaching STEM indicated that STEM lessons use various levels of inquiry learning methods. There are two common inquiry methods in STEM education and these are; free inquiry method where the teacher does not give much background information to the learners about the concept, and guided inquiry method where the teacher provides background information to the learners about the concept to be learnt (Ring, 2019). Lessons using the two inquiry methods were studied at junior secondary school level to determine which methods helps learners to understand the concepts, the study revealed that learners who participated in the guided inquiry method had deeper understanding of the concepts. Further, the study revealed that teachers may understand the benefit of inquiry methods in STEM education, but struggle to provide a good STEM lessons if their learners do not fully understand the goals of the lesson.

2.3 Perspectives and Implementation Approaches in STEM Education

It is widely accepted that STEM education emerged with the aim of transforming education to address various environmental and socio-economic challenges that many societies face. A study by Permanasari, Rubini and Nugroho (2021) revealed that STEM education in Indonesia has become a commitment for all stakeholders in education to increasing the skilled human resource in STEM fields for individual and national development.

STEM education in Indonesia is mostly implemented at the junior and secondary school levels and limited at the university level. In addition, the widely accepted STEM implementation approach is the project-based learning (PjBL) where learners construct meaning based on a challenging task or problem that leads them to investigate, make decisions, design, and finally, come up with tangible products using knowledge and ways of thinking from all the four disciplines of STEM. Implementation of STEM education in Indonesia faced challenges such as inadequate infrastructure and the disconnection between teacher professional development programmes and the demands of STEM education (Suwarma & Kumano, 2019).

Another study by Bermingham and Engmann (2012) in Ghana that focused on the benefits of STEM education revealed that Ghana approached STEM education implementation the establishment of innovative initiatives for improving the implementation of STEM education in secondary schools. One of the innovations is that Ghana developed hundred and eight communal science resource centres to improve the implementation and sustainability of STEM education. As a result of this initiative, a significant improvement in the percentage of candidates who passed the West Africa School Certificate Examinations between 2005 and 2010 was found. The significant improvement in the performance of the learners was due to easy access to study materials through the communal resource centres, which enabled learners to collaborate and learn at their own pace. Thus, such innovative initiatives as the establishment of communal science resource centres like in the case of Ghana, demonstrate the significant commitment by the government and other stakeholders in implementing STEM education for sustainable development.

A study by Lwakabamba and Lujara (2003) focused on the impact of the implementation of STEM education in Rwanda. They found that STEM was implemented in the form of projects that incorporated concepts from all the four disciplines of STEM to come up with desired products and services. One of the approaches in the implementation of STEM was the establishment of the Kigali Institute of Science, Technology, and Management (KIST) to run STEM projects in Rwanda. The academic programmes in this project were tailored to produce skilled technicians at different levels to meet the needs of the labour market (Rwanamiza, 2004). The study also revealed that continuing education programmes were introduced at KIST to provide short courses so that technicians and artisans would update their knowledge and become more efficient. There was also a production department

established to oversee several income-generating project activities under the STEM project at KIST. The project emphasised on locally produced technology and entrepreneurship skills, which resulted in the building of biogas and bio-latrine plants for schools, prisons, and hospitals in Kigali (Lwakabamba and Lujara, 2003). In addition, energy-saving stoves and efficient bread-making ovens were also developed in Rwanda through STEM projects, to benefit the local communities.

Another implementation approach to STEM education that Rwanda adopted was collaboration in projects and research at the university level. One such project collaboration is where the Swedish International Development Authority (SIDA) funded twelve collaborative projects between the University of Rwanda (UR) and twelve Swedish universities, in 2013. The main objective of these projects was to increase the production and use of scientific knowledge in solving real-life problems in Rwanda. Therefore, it is argued that the study by Lwakabamba and Lujara (2003) contributes to better policy-making and improved products or services produced by the private sector and civil society organisations in Rwanda (Rwanamiza, 2004). This current study takes note of the implementation approach and impressive progress made by Rwanda through several STEM implementation approaches, such as encouraging locally produced technologies, empowering youths both in the formal and informal sectors with the scientific and entrepreneurial skills needed for the labour market and for their survival. The implementation approach by Rwanda focuses on skills development at the tertiary level of education and is limited at the junior and secondary school levels. From this literature, it is noted that, there is inadequate literature on Zambia with regard to what implementation approach and how the scientific knowledge from STEM education is likely to contribute to achieving productivity, job creation, and sustainable economic development for Zambia.

2.4 Teacher Professional Development for STEM Education

In line with the global interest and national efforts in STEM education, efforts should be made particularly in building the capacity of teachers to implement STEM education, and one way to achieve teacher capacity building for STEM education is through teacher professional development trainings. Teacher professional development is one of the crucial components of any pedagogical and curricula reforms such as STEM education in this context. This is evidenced in a study by Jong, Song, Soloway and Norris (2021) who observed that many promising educational reforms and innovations have failed because the programmes have not

helped the teachers to develop their capacity to fully understand and implement the new innovations. In addition, although STEM education places emphasis on learner-centredness and learners' constructive role in the learning process, teachers still play a critical role in supporting the learners to achieve the learning outcomes that underlie STEM education. Therefore, teacher professional development in the STEM education implementation becomes critical.

A study by Goodnough and Stordy (2014) that focused on teachers' perceptions of what constitutes effective teacher professional development in STEM education revealed that for teachers to effectively implement STEM education, it is important to create professional development opportunities that are coherent and meaningful for teachers to gain confidence and understanding of STEM education. Further, the study also revealed that teacher professional development in STEM education should not only focus on STEM concepts but also on the teaching and learning process, helping the teachers to effectively implement STEM education. In addition, Mpofu (2020) added that teachers require a lot of support systems in terms of implementation frameworks, professional development, and resource development in order to effectively implement STEM education at the classroom level.

Another study by Polgampala and Huang (2017) in Sri Lanka, on STEM teachers' professional development and training found that teacher professional development and training in STEM education are the driving forces behind the implementation of STEM education. In addition, the finding is supported by Diana and Sukma (2021) who argued that one of the major goals of STEM education is to encourage a shift from a teacher-centred classroom, where learners are passive consumers to a learner-centred environment where learning is an active transactional process. Thus, from the literature, it is noted that continuous capacity-building for teachers in STEM education is critical for the successful and sustainable implementation of STEM education.

Further, a study by Ritz and Fan (2015) on STEM and technology education revealed that there have been discussions about STEM education across the globe, but little has been done to build the confidence and the capacity of teachers to deliver the kind of STEM education in line with the local community needs and developmental aspirations. Ritz and Fan (2015) suggest that adopting STEM education should provide teacher professional development to equip teachers on how they could build their confidence to teach in an interdisciplinary approach and incorporate STEM in their teaching of mathematics and science.

Teacher professional development for STEM education may be achieved through seminars, conferences, workshops, lesson study, and in-service teacher training programmes aimed at enhancing teachers' collaborations, competencies and understanding of STEM education so that they can design appropriate instructional methods in line with STEM education intentions. Prideaux and Faulkner (2007) argue that clear guiding framework, professional development of teachers, and engagement of stakeholders are key factors of effective and sustainable STEM education implementation.

2.5 Technology Integration in the Implementation of STEM Education

The other crucial aspect in the implementation of STEM education is technology integration. Technology integration refers to the strategic incorporation of various digital tools, resources, and platforms to enhance teaching and learning experiences within and across STEM disciplines. It also involves the use of technology to facilitate inquiry-based learning, problem-solving, collaboration and creativity in ways that support the development of skills and competencies in the learners (Ritz & Fan, 2015). In addition, technology provides opportunities for learners to engage in meaningful inquiry and experimentation through online searches for information, data analysis software, modelling tools, and digital simulations (Zendler, Sietz & Klaudt, 2018). Through such opportunities provided by technological tools, learners can explore real-world problems, conduct experiments, generate hypotheses, and acquire a deeper understanding of the concepts in STEM disciplines. According to Bingimlas (2009), the integration of technology in the teaching and learning of mathematics and science provides opportunities for learners to operate in the information age, where the motivation to learn and application of scientific thought to problem-solving are enhanced by technology. He further argues that integration of technology is also key in the development and implementation of STEM education as STEM education aims at producing a learner who is analytical, creative, innovative, and self-directed in order to survive and address 21st century challenges that require multidisciplinary and technological solutions.

A study by Wang and Yuan (2024) on STEM education in the era of artificial intelligence revealed that, the increase in the use of artificial intelligence to solve human problems presents challenges for the implementation of STEM education. As such, STEM education needs to incorporate technologies to suit the era of artificial intelligence. In responding to the challenges of the 21st century, implementation of STEM education in the era of artificial intelligence focuses on an interdisciplinary education system, sharing of quality resources,

promotion of digital integration into science and technology education, construction of digital platforms, and building of STEM education ecosystems. Thus, the demands generated in the era of artificial intelligence can be addressed through the implementation of STEM education (Wang & Yuan, 2024). Lukychova, Osypova and Yuzbasheva (2022) claim that the systemic integration of technologies such as computer simulations and virtual laboratories in the implementation of STEM education increases the efficiency of training, Curiosity and motivation for learners, quality of knowledge in the field of natural sciences, and contributes to the development of key competencies needed to address 21st century challenges.

2.6 Partnerships in the Implementation of STEM Education

Partnerships and collaborations are also crucial to the successful implementation of STEM education at any level. This is because STEM education itself is an interdisciplinary approach in nature requiring expertise from different disciplines. Community partnerships in the implementation of STEM education involve collaboration among educational institutions, industries, government agencies, and other community stakeholders to enhance STEM education opportunities for learners (Diana & Sukma, 2021). These partnerships leverage the expertise, resources, and networks of diverse community organisations to support STEM education initiatives. According to Chiu, Price and Ovrahim (2015), community partnerships may also enrich curriculum and instructional discourse by providing real-world context and relevance to classroom learning in STEM education. A study by Watters and Diezmann (2013) on community partnerships for fostering interest and engagement in STEM education revealed that, formation of partnerships between schools and industry in which learners have high degree of autonomy and sense of responsibility, is critical to the disposition towards the sustainable implementation of STEM education.

The study observed that, partnerships between schools and industry can foster innovation and connect the young people in schools to the real world situations (Watters & Diezmann, 2013). In addition, Watters and Diezmann (2013) in Chiu, Price and Ovrahim (2015) noted that successful STEM programmes have partnerships within the community, industry, business, and various stakeholders. These partnerships promote STEM education and make connections between education and real-world experiences. Partnerships that schools form outside of their walls provide many opportunities for learners and teachers. Universities, industries, and different informal institutions and organisations support STEM education implementation in different ways and provide learners with different enrichment

opportunities, teachers with different learning opportunities, and schools with grants and other monetary support to sustain their programmes (Chiu, Price & Ovrahim, 2015).

It is, therefore, noted that STEM education implementation, as understood by many scholars is an interdisciplinary innovative educational approach that requires expertise knowledge and support from various stakeholders in the community, such as industry and business representatives, universities, government agencies, and non-governmental organisations. In an ever-changing world, facing various challenges ranging from socioeconomic to environmental challenges, partnerships with various stakeholders in STEM education aimed at sharing multidisciplinary expertise are needed to address current and future problems. The current study takes into consideration the importance of partnerships and collaborations among various individuals in the field of science and technology education as one of the ways of enhancing sustainable STEM education implementation.

2.7 Future Direction for STEM Education

STEM education is continuously evolving in order to meet the demands of the ever-changing world. STEM education is viewed as an innovative education approach that fosters analytical, critical thinking, and creativity in the learners, preparing them to address various environmental and socioeconomic challenges which societies face and that require multidisciplinary skills and expertise solutions. Therefore, the approach and context for STEM education implementation should take into consideration future trends and directions for STEM as the industry and workforce demands that require STEM solutions keep changing with time. The implementation of STEM education also takes into account emerging trends, challenges, and opportunities, such as the impact of advancements in technology, changes in workforce demands, and evolving education policies.

A study by Shahali, Ismail and Halim (2017) revealed that the way forward for Malaysia's future direction of STEM education lies in strengthening the quality of STEM education curricula, enhancing the professionalism of STEM teachers through a long-term professional development plan, and creating more opportunities for informal STEM activities through collaborations. The direction that the Malaysian Government has taken in placing great emphasis on STEM education is in line with the Malaysian National Economic Model (NEM), aimed at increasing the number of human resources capital in STEM-related fields to four hundred and forty-three thousand for national economic development (Shahali, Ismail & Halim, 2017). The study also revealed that the interdisciplinary nature of STEM education

takes into consideration that the world keeps changing, hence, presenting an opportunity for integrating STEM into other fields like the arts, humanities, and social sciences in order to provide a holistic understanding of the present and future challenges that require multidisciplinary solutions.

Besides the changes in workforce demands on the implementation of STEM education, the other future challenge is the impact of advancements in technology. Advancements in technology entail that the world is in the process of transitioning from the digital revolution, or the information age, to the age of synthesis (Nadelson & Seifert, 2017). Thus, STEM education, in the age of synthesis and advancements in technology, promotes new domains of expertise such as evaluating and applying seemingly disparate information, accommodating the accelerated emergence of new knowledge and sophisticated technologies, preparing for transdisciplinary careers, and merging traditional disciplines to better meet the needs of citizens in the 21st century. In addition, Nadelson and Seifert (2017) claim that developing careers such as biomedical nanotechnology engineering requires STEM professionals who work in collaboration using information from computing, biology, medicine, chemistry, and engineering to synthesise new approaches and solutions, resulting in novel and innovative products and procedures for addressing complex health-related issues currently, and in future.

2.8 Knowledge Gap Identified in the Literature Reviewed

From the literature reviewed, it was observed that STEM education has become a widely accepted innovative education approach for transforming science education and making it applicable and relevant to solving real-world problems. It was also learnt through the literature review that teachers viewed STEM education as an interdisciplinary and innovative approach to science education that incorporates the different modes of thinking from the four disciplines of Science, Technology, Engineering and Mathematics hence, providing the learners with critical thinking, scientific and problem-solving skills, and creativity (Hooker, 2017).

Literature review also showed so that some teachers did not have adequate understanding of STEM education because they had limited exposure to information on STEM education (Ring, 2019). The implication of this is that teachers would varying understanding of STEM education based on the information they have. This would affect their implementation of STEM education in the teaching and learning process. In addition, the other knowledge gap identified through literature review is that most literature focused on pre-service and primary

school teachers' understanding of STEM education, hence making the current study necessary to be undertaken to establish teachers' understanding of STEM education at secondary school level.

The other knowledge gap that was identified is that, despite teachers' acknowledgement of the significance of the teaching methods in the implementation of STEM education, literature showed that there a general lack of understanding of which teaching methods are recommended for STEM education. According to MoGE (2020), some teachers indicated question and answer, discussion and group work as teaching methods when actually these are not primarily teaching methods, but strategies that can be found in any of the teaching methods. Hence, the lack of understanding of what teaching methods are and identifying which teaching methods are recommended for STEM education makes the current study necessary to be undertaken.

STEM education implementation approaches are context-based in line with the needs of the local communities. For example, in Indonesia, STEM education has been implemented through the project-based learning (PjBL) approach to build a scientific, mathematical, and technological way of thinking in the learners in secondary schools. This approach worked for Indonesia, as the learners who used PjBL at secondary school were able to apply the principles of optics and incorporated engineering and technology concepts to produce a simple projector (Khotimah, Adnan & Murtiyasa, 2021). In Rwanda, STEM has been implemented through collaborative STEM-related projects at university level with an emphasis on the usage of locally available technologies to produce products and empowering the young people with the scientific, technological, and entrepreneurial skills needed for their survival in the world of business (Lwakabamba & Lujara, 2003).

In Zambia, STEM education was implemented at secondary school level as one way of striving to achieve the national developmental agenda as stipulated in the Seventh National Development Plan (GRZ, 2017). However, there is inadequate literature on the implementation framework to guide the implementation of STEM education in line with the STEM education goals for Zambia, such as economic diversification, value addition to natural resources, and job creation. Therefore, this study is necessary to be undertaken to establish insights in the implementation and framework(s) that could be adopted for improved and sustainable STEM education implementation.

2.9 Chapter Summary

This chapter presented the literature reviewed on various studies conducted on teachers' understanding of STEM education, teaching methods in STEM education implementation, implementation approaches for STEM education, teacher professional development for STEM education, partnerships in the implementation of STEM and future directions for STEM education. The chapter concluded by present the knowledge gaps identified in the literature that made this study necessary to be undertaken.

Literature indicated that majority of teachers have an understanding of STEM education as an interdisciplinary education approach that enhances analytical thinking skills using the concepts from the four disciplines of STEM to solve real-life problems. In addition, it was noted that teachers have different understanding and definitions of STEM education especially the engineering and technology components of STEM.

Literature further indicated that problem-based learning, inquiry, projects and field trips were the widely constructivist recommended teaching methods for STEM education. Teachers understood the importance of teaching methods in the teaching of STEM. However, some teachers indicated, discussion as a teaching method. This showed that some teachers had challenges distinguishing teaching methods from strategies.

STEM education is widely implemented as a teaching approach at secondary school level. The widely accepted implementation framework was the project-based learning (PjBL), where learners work on a project and use concepts from STEM to come up with tangible products. Further, literature also revealed that community partnerships, technology integration and teacher professional development are critical in the implementation of STEM education. In addition, it was noted that STEM education implementation takes into considerations future trends such advancements in technology and dynamics in the workforce demands.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Overview

The chapter gives a description of the methods that were used in carrying out the study. It presents the research design, research site, target population, sample size, sampling technique, data collection instruments, data analysis, data validity and reliability, limitations and ethical considerations.

3.1 Research Design

This study used a case study research design. Yin (1989: 1) defines a case study as "an empirical inquiry that (a) investigates a contemporary phenomenon within its real-life context, (b) the boundaries between phenomenon and context are not clearly evident and (c) multiple sources of evidence are used." The choice for the case study research design is the fact that it has the ability to consider the phenomenon under investigation in its context and the dynamic characteristics that cannot easily be understood through observations from a distance.

3.2 Research Site

The study was conducted in Lusaka District at a selected STEM secondary school. The school was purposively selected on the basis that it is one of the oldest technical secondary schools and one of the schools that were selected as pilot schools for the STEM pilot programme, in 2020.

3.3 Target Population

The target population for this study included all teachers and administrators at the selected STEM secondary school in Lusaka District.

3.4 Sample Size

In this study, a sample size of thirteen (13) respondents was considered, and this included nine teachers who taught STEM subjects, three heads of departments, and one head teacher at the selected STEM secondary school, as summarised in Table 3.1.

Table 3. 1: Sample Size and Division

Department/Section	Coding of Respondents	Number of Respondents
Mathematics	Mathematics Teachers- Tm Tm1, Tm2, Tm3	3
Biology	Biology Teachers-Tb Tb1, Tb2	2
Chemistry	Chemistry Teachers-Tc Tc1, Tc2	2
Design and Technology	Design and Technology Teachers-Tdt Tdt	1
Physics	Physics Teacher- Tp Tp1	1
Science	Head of department-Science	1
Mathematics	Head of department-Mathematics	1
Design and Technology	Head of department- design and technology	1
Administration	Head Teacher-Administrator	1
Total number of respondents		**13**

Field data, 2023

3.4.1 Characteristics of the Respondents

Out of the 13 that participated, 9 were males, while 4 were females. Respondents aged 26 to 30 years were 5, respondent aged 31 to 35 years was 1, and those aged 36 and above were 7.

Respondents with 3 to 5 years of teaching experience were 4, those with 6 to 8 years of teaching experience were 2, and 4 respondents had above 9 years of teaching experience. Respondents with 1 to 3 years of heading a department were 2 and, 1 respondent had 7 years and above of heading a department.

Respondents who were trained at the University of Zambia were 6, those who were trained from the Copperbelt University were 3, 1 from Kwame Nkrumah University, 1 from St. Eugine University, 1 from Kabwe Institute of Design and Technology, and 1 from Queens Land University (Australia). Respondents with bachelor's degree were 11 while the other 2 were master's holders. Table 3.2 provides summary information on the characteristics of the respondents.

Table 3. 2: Characteristics of the Respondents

VARIABLE	VALUES	FREQUENCY
Gender	Male	9
	Female	4
Age	26 – 30 years	5
	31 – 35 years	1
	36 – 40 years	2
	41 years and above	5
Years of experience in the teaching service	3 – 5 years	4
	6 – 8 years	2
	9 years and above	5
Year of experience as Head of Department (H.O.D)	1 – 2 years	1
	3- 5 years	1
	6 years and above	1
University attended	The University of Zambia	6
	Copperbelt University	3
	Kwame Nkrumah University	1
	St Eugene's University	1
	Kabwe Institute of Design and Technology	1
	Queens Land University	1
Qualification obtained	Bachelor's Degree	11
	Master's Degree	2

3.5 Sampling Technique

The researcher used homogenous purposive sampling to select the respondents in this study. According to Creswell (2009), homogeneous sampling is a purposive sampling technique whose units (for example, people, cases, and others) share the same (or very similar) characteristics or traits (for example, a group of people that are similar in terms of background, occupation, practice, beliefs, experiences, and others). In addition, a homogeneous sample is often chosen when the research questions used are specific to the characteristics of the particular group of individuals of interest. Therefore, homogenous purposive sampling in this study was done by purposively selecting only teachers and heads

of departments that implemented STEM education at the selected STEM secondary school in Lusaka district.

3.6 Data Collection Instruments

The researcher developed the interview guides that were used to collect data from the selected respondents in this study. Interviews were appropriate for collecting data in this study as they facilitate obtaining of direct explanations and opinions about a phenomenon, from the respondents. Best and Khan (2006) claim that no system of inquiry can be as revealing as an interview. It is natural and provides in-depth information about a phenomenon under investigation.

3.7 Data Collection Procedure

Primary data was collected through the use of semi-structured interviews. This involved carrying out face-to-face interviews with the STEM teachers, heads of departments, and head teacher at the selected STEM secondary school, using the designed semi-structured interview guides indicated in the appendices 2, 3 and 4 respectively. Data collection process took a duration of one week in which the researcher visited the school every day. The researcher accessed the school and the respondents on permission and appointment from the school management. Individual interviews for each respondent were conducted on appointment in the respondents' offices during their free time as data collection was conducted at the time the school was in session, this was the only time teachers could be accessed for interviews. The researcher was taking notes on the responses as they came from the respondents.

Secondary data was collected through document analysis. The researcher reviewed the physics STEM syllabus and some selected lesson plans. The physics STEM syllabus and the lesson plans were accessed on request from the science head of department.

3.8 Trustworthiness of Collected Data

This section is concerned with some of the ways in which quality can be achieved and how it can be demonstrated in qualitative research. Therefore, in this study, the researcher relied on four characteristics of data trustworthiness; credibility, transferability, confirmability, and dependability as suggested by Lincoln et al., (2011).

3.8.1 Credibility

Credibility addresses the need to ensure that data is interpreted appropriately and deals with patterns in their entirety (Creswell, 2009). Several actions were taken to ensure the credibility of the data collected in this study. These included regular faculty seminar presentations of the study and briefing with the study supervisor, giving adequate time for engagement with research participants, conducting in-depth interviews to clarify, or expand on findings, and keeping notes to track decisions and rationale.

3.8.2 Transferability

Transferability speaks to the ability to transfer findings from data to other settings. Additionally, it addresses the qualitative researcher's belief that all social and behavioural phenomena are context-bound or context-relevant (Gunawan, 2015). This study demonstrated transferability through purposive sampling to maximise the collection of in-depth information. The collection of 'thick', descriptive data, including the use of field notes on issues that emerged in the research process and clear descriptions of the selection of the respondents to participate in the study, were demonstrated. Ultimately, the purpose was not to transfer the findings of this study to other studies but rather to clarify understanding of the phenomena from the perspective of the participants.

3.8.3 Dependability

The dependability of qualitative studies addresses the concern for the data to remain stable over time and in various conditions (Gunawan, 2015). This study demonstrated dependability by providing descriptive details of methods used to gather, analyse, and interpret data. The authenticity of the data was clarified with participants and interpreted, examined, and discussed in the faculty seminars.

3. 8.4 Confirmability

Confirmability is the final step in demonstrating trustworthiness and refers to the objectivity or neutrality of the data (Lincoln et al., 2011). This study addressed confirmability by establishing notes after in-depth interviews on planned activities related to data collection and keeping records of drafts of reports reviewed by the study supervisor at every stage.

3.9 Limitation of the Study

The following were the limitations of the study:

- Some of the potential respondents that were supposed to participate in the study were not available at the time of data collection due to their busy schedules, as data was collected when the school was in session. This limitation may have affected the study in such a way that the four disciplines of STEM were not equally represented by the expected number of three respondents in each STEM subject area. However, the findings were still valid as each subject area was represented and the representatives were the teachers that were teaching STEM at the time it was implemented.
- Some documents that were supposed to be reviewed, such as lesson plans and syllabi in biology, mathematics, chemistry and design and technology were not available as it was found that most teachers had discarded the material after the STEM programme was discontinued. This limitation may have affected the study in such a way that the teaching methods and evaluations in the different disciplines of STEM may not have been captured holistically. The effect of this limitation was minimized by covering the teaching methods in the interviews involving each respondent.

3.10 Data Analysis

Collected data were analysed thematically. The analysis process involved six steps as follows: familiarisation, generation of codes, generation of themes, reviewing of themes, naming of themes, and report writing (Clarke, Braun & Hayfield, 2015). Thematic analysis is appropriate for analysing qualitative data because it deals with respondents' views, experiences, values, and knowledge about a phenomenon under investigation. During the familiarisation step, the researcher read several times through all the collected data to develop a thorough understanding of the data before going to the next step. This was followed by the generation of codes, where the researcher compiled the responses from the respondents in a systematic way, and considered codes, or patterns of relevance to the research questions. The next step was the generation and review of themes in which the researcher examined the codes, identified related patterns that addressed specific research questions, and grouped them into themes. In the last step, the researcher named the themes in line with the research questions. Further, responses related to the research questions were transcribed into textual information and presented in the form of descriptions, explanations, and interpretations for simplified understanding.

3.11 Ethical Considerations

The study took into account a range of ethical considerations. During research, respondents should not be put in situations that might expose them to the risk of physical or psychological harm. The following ethical considerations were taken during data collection.

i. Before going for data collection, ethical clearance was sought from the University of Zambia research ethics committee, and permission for the researcher to go for data collection in the field was granted as indicated under appendix 8.
ii. The researcher also sought permission from the Office of the District Education Board Secretary (DEBS) to go to the selected school.
iii. None of the respondents participated in the study without prior information on the procedure and the purpose of the study. Therefore, voluntary participation and consent were the basis upon which respondents participated in the study. The researcher ensured that prior appointments between the researcher and the respondents were made so as not to inconvenience the respondents, as the study was conducted at the time school when was in session.
iv. Confidentiality and anonymity were ensured by not revealing the respondents' names and personal details.
v. Respondents were assured that the information they gave was to be used for the purpose of this study only and not for any other purposes.

3.12 Chapter Summary

This chapter has presented the methodology that was used in this study under the following headings: research design, study site target population, sample size, sampling procedures, data collection instruments, data collection procedure, trustworthiness of the collected data, limitations of the study, data analysis, and ethical considerations.

CHAPTER FOUR

PRESENTATION OF FINDINGS

4.0 Overview

This chapter presents the research findings from data collected on the insights into the implementation of STEM education at a selected STEM secondary school in Lusaka District. The findings were presented under the following themes; teachers' understanding of STEM education, teaching methods teachers were using to teach STEM and sustainable STEM education implementation.

4.1 Research question one: Teacher's Understanding of STEM Education

When finding out what teachers understood by STEM education, three aspects came up, and these included (a) linking what is learnt in theory to the practical reality (application), (b) a learner-centred education approach, and (c) technology integration in the teaching and learning of science and mathematics.

4.1.1 Linking What is Learnt in Theory to the Practical Application

The study found that teachers perceived STEM education as an educational approach that strengthens the links between what is learnt in theory and application in real-life problem-solving. Application in this context means using the concepts and thinking skills learnt in STEM education to solve real-life problems. One mathematics teacher (Tm2) said:

> *STEM education came as a result of a check on how things are done in the 21st Century. 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.*

4.1.2 Learner-centred Education Approach

Further, some respondents perceived STEM education as an education approach that puts the learner at the centre of the teaching and learning process. It allows the learners to learn by discovering solutions to open-ended problems and constructing meaning on their own, as one biology teacher (Tb1) explained:

> *STEM 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.*

Another respondent viewed STEM education as a learner-centred education approach, from the constructivist perspective. The respondent, a physics teacher (Tp1), said: "*I understand STEM as the learner-centred approach where learners construct their own knowledge with the guidance of the teacher. Behind STEM, we look at a learner as the source of knowledge.*"

A chemistry teacher (Tc1) understood STEM education as an education approach for equipping learners with science and technology skills needed for 21st Century. He said that "*STEM is an approach in science education of equipping the learners with science knowledge and technology.*"

4.1.3 Technology Incorporation in the Teaching of Science in the 21st Century

Further, teachers also understood STEM education as an educational approach that incorporates technology in the teaching and learning of mathematics and science in order to enhance critical thinking, innovation, and creativity in the learners, as evidenced by a respondent from the mathematics section (Tm1), who narrated that;

> *STEM education is the incorporation or application of technology in the teaching of mathematics and science, such as the use practical questions and allowing the learners to bring out their ideas to answer the questions. It also involves the use of technologies such as computer simulations to help learners to connect what is learnt in theory to the practical world.*

This view is in line with the view of another mathematics teacher who viewed STEM education as the incorporation of technology in the teaching of science, and mathematics, following that teaching and learning in the 21st century is technologically driven, and technology adds value and motivation for learners to learn. In view of STEM education, the mathematics teacher (Tm2) said that "*STEM education is an education approach that emphasises the use of technology in the 21st century teaching where technology has become the way of doing things."*

Further view of STEM education in line with technology incorporation in education, was given by the head of department, who explained that;

> *The current curriculum* [2013] *has not given us the kind of learners that we need, hence the introduction of STEM. STEM is an approach to producing a learner who is technology-oriented, analytical, creative, and a critical thinker. You* [researcher] *need to understand that we have 21st century learners who interact so much with technology, so even in the way we teach them, we need to use more of technology.*

Thus, from the view point of the teachers at the selected STEM secondary school, STEM education is an innovative educational approach that puts the learner at the centre of the teaching and learning process. It is also an integration of technology in the teaching and learning process in order to link what is leant in theory to practical application of the skills in solving real-life problems.

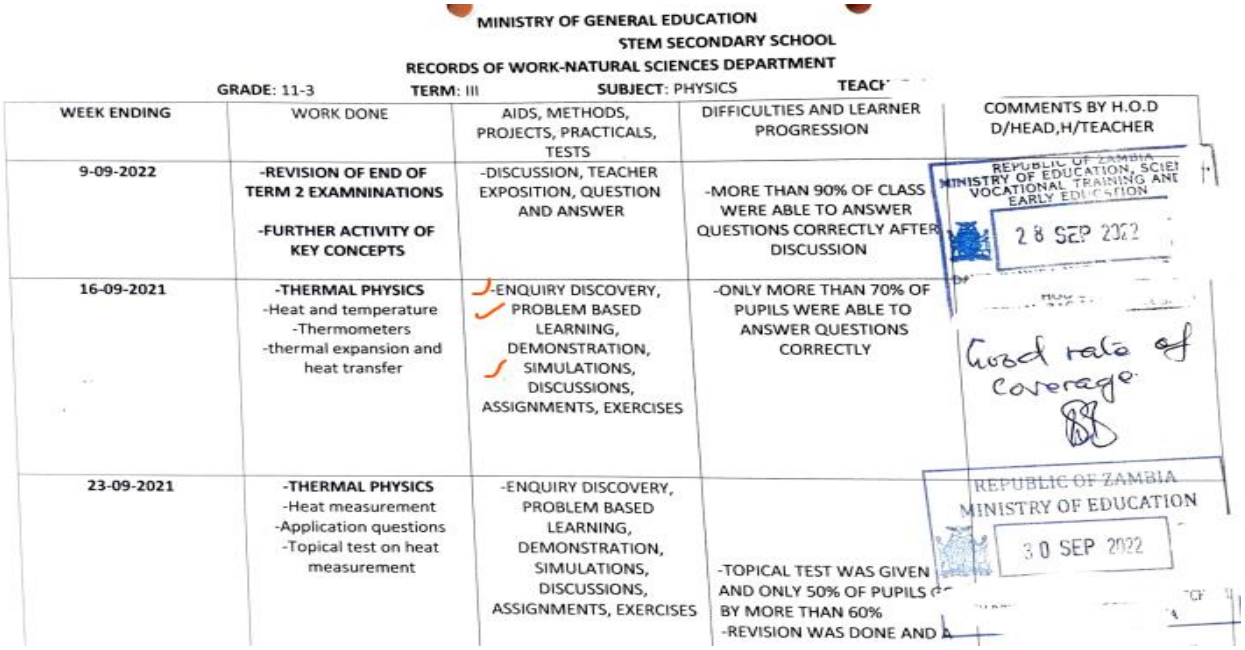
4.2 Research question two: Teaching Methods Teachers were using to Teach STEM

This section presented the findings on some of the teaching methods that teachers were using to teach STEM before it was discontinued at the selected STEM school as follows:

4.2.1 Problem-based Teaching

Teachers utilised project-based teaching as one of the teaching methods under STEM education programme. They used problem-based teaching in such a way that they would identify a problem or project that learners would carry out individually or in small groups and present their solutions or product respectively within the given time. One respondent, a physics teacher (Tp1) narrated that: "*I used problem-based teaching method as my best method, where learners were allowed to find solutions to open-ended problems on their own*."

In addition, a records of work in physics was reviewed to establish the teaching methods that the teachers were using to teach STEM at the selected STEM secondary school. The findings revealed that small group discussions and problem-based teaching were among the common methods that were used as evidenced in Figure 4.1.



MINISTRY OF GENERAL EDUCATION
STEM SECONDARY SCHOOL
RECORDS OF WORK-NATURAL SCIENCES DEPARTMENT
GRADE: 11-3 TERM: III SUBJECT: PHYSICS TEACH

WEEK ENDING	WORK DONE	AIDS, METHODS, PROJECTS, PRACTICALS, TESTS	DIFFICULTIES AND LEARNER PROGRESSION	COMMENTS BY H.O.D D/HEAD,H/TEACHER
9-09-2022	-REVISION OF END OF TERM 2 EXAMNINATIONS -FURTHER ACTIVITY OF KEY CONCEPTS	-DISCUSSION, TEACHER EXPOSITION, QUESTION AND ANSWER	-MORE THAN 90% OF CLASS WERE ABLE TO ANSWER QUESTIONS CORRECTLY AFTER DISCUSSION	REPUBLIC OF ZAMBIA MINISTRY OF EDUCATION, SCIENCE VOCATIONAL TRAINING AND EARLY EDUCATION 28 SEP 2022
16-09-2021	-THERMAL PHYSICS -Heat and temperature -Thermometers -thermal expansion and heat transfer	-ENQUIRY DISCOVERY, PROBLEM BASED LEARNING, DEMONSTRATION, SIMULATIONS, DISCUSSIONS, ASSIGNMENTS, EXERCISES	-ONLY MORE THAN 70% OF PUPILS WERE ABLE TO ANSWER QUESTIONS CORRECTLY	Good rate of coverage
23-09-2021	-THERMAL PHYSICS -Heat measurement -Application questions -Topical test on heat measurement	-ENQUIRY DISCOVERY, PROBLEM BASED LEARNING, DEMONSTRATION, SIMULATIONS, DISCUSSIONS, ASSIGNMENTS, EXERCISES	-TOPICAL TEST WAS GIVEN AND ONLY 50% OF PUPILS BY MORE THAN 60% -REVISION WAS DONE AND	REPUBLIC OF ZAMBIA MINISTRY OF EDUCATION 30 SEP 2022

Figure 4. 1: An Extract of the Physics Records of Work. Field Data (2023)

4.2.2 Small Group Discussions

Apart from problem-based teaching, the study also found that two teachers used small group discussions where learners could be allowed to discuss, debate, criticise issues and learn from each other. This method also supports problem-based teaching in the sense that learners are able to express their ideas, creativity and misconceptions through debates and discussions. In this case, at the end of the discussion, the teacher would summarise the main points and clarify the misconceptions that the learners might have on the particular concepts. This was indicated by a respondent, a mathematics teacher (Tm3) who said: "*I mostly used group discussion methods where learners could discuss and come up with their own solutions."*

Group discussion method was supported by the response from another respondent, a chemistry teacher (Tc1) who said*: "I used group discussions most of the times as STEM required that learners are guided to generate answers and solutions on their own. We also used research and projects as a way of guiding learners."*

4.2.3 Practical Scenarios and Computer Simulations

The study further revealed that teachers at the selected STEM secondary school used practical scenarios and computer simulations in their teaching in order to bring about understanding of the concepts in the learners, as one mathematics teacher (Tm1) indicated that:

> *The emphasis of STEM was more on the learner-centred approach, allowing learners to do things on their own. We also encouraged learners to research on their own., except there was a lot of miscommunication in the way the learner-centred approach was handled. A lot of misconceptions were identified in the learners, but teachers were not allowed enough time to clarify the misconceptions that learners had as the learning was determined by the learners themselves. We also used computer simulations to demonstrate some abstract concepts.*

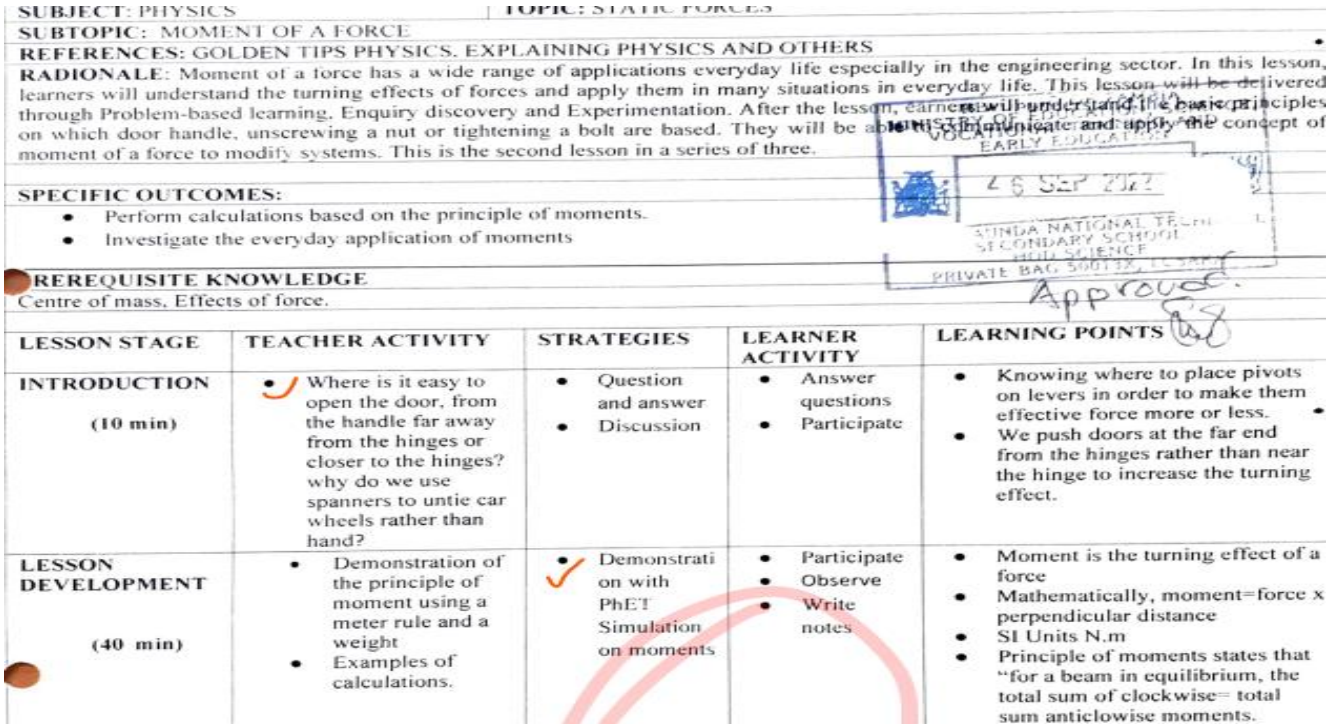
A biology teacher (Tb2) said:

> *Practical scenarios, and more of available technologies were used for teaching under STEM education. I relied on technology because the programme was introduced, but there were no STEM textbooks. STEM education also involved the use of technology tools, such as links, videos, and computers, in the delivery of lessons to make sure that information is not directly transmitted to the learners but allow learners bring out their ideas.*

Further, a chemistry teacher (Tc1) stated that: *"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."*

Another teacher from the biology section (Tb1), mentioned field trips to the sites for learners to have practical/experiential learning as one of the methods teachers used to teach STEM at the selected STEM secondary school. She explained her experience with STEM education as follows: *"Field trips were encouraged in STEM, we needed to take learners to places like* Munda Wang. *I took my learners to* ***Trade Kings Manufacturing Industry*** *to go and learn how enzymes are applied to make detergent paste."*

To further establish what teaching methods teachers were using in STEM education, a Grade 10 physics lesson plan was reviewed. The findings revealed that computer simulations such as PhET were used to demonstrate some abstract concepts as indicated in Figure 4.2.



SUBJECT: PHYSICS | TOPIC: STATIC FORCES

SUBTOPIC: MOMENT OF A FORCE

REFERENCES: GOLDEN TIPS PHYSICS. EXPLAINING PHYSICS AND OTHERS

RADIONALE: Moment of a force has a wide range of applications everyday life especially in the engineering sector. In this lesson, learners will understand the turning effects of forces and apply them in many situations in everyday life. This lesson will be delivered through Problem-based learning, Enquiry discovery and Experimentation. After the lesson, learners will understand the basic principles on which door handle, unscrewing a nut or tightening a bolt are based. They will be able to communicate and apply the concept of moment of a force to modify systems. This is the second lesson in a series of three.

SPECIFIC OUTCOMES:

- Perform calculations based on the principle of moments.
- Investigate the everyday application of moments

PREREQUISITE KNOWLEDGE

Centre of mass. Effects of force.

LESSON STAGE	TEACHER ACTIVITY	STRATEGIES	LEARNER ACTIVITY	LEARNING POINTS
INTRODUCTION (10 min)	• Where is it easy to open the door, from the handle far away from the hinges or closer to the hinges? why do we use spanners to untie car wheels rather than hand?	• Question and answer • Discussion	• Answer questions • Participate	• Knowing where to place pivots on levers in order to make them effective force more or less. • We push doors at the far end from the hinges rather than near the hinge to increase the turning effect.
LESSON DEVELOPMENT (40 min)	• Demonstration of the principle of moment using a meter rule and a weight • Examples of calculations.	• Demonstration with PhET Simulation on moments	• Participate • Observe • Write notes	• Moment is the turning effect of a force • Mathematically, moment=force x perpendicular distance • SI Units N.m • Principle of moments states that "for a beam in equilibrium, the total sum of clockwise= total sum anticlowise moments.

Figure 4. 2: Extract of the Physics STEM Lesson Plan. Field Data (2023*)*

4.2.4 Research

Research was also one of the teaching methods teachers used for teaching during STEM education implementation at the selected STEM secondary school. Research enabled the learners to be actively involved in the teaching and learning process and generation of knowledge as they were able to come up with research projects centred around their already existing knowledge and conceptions, work on them, and then present their findings with the guidance of the teacher. Findings indicated that research was one of the methods that made teaching in STEM education interesting, even though it needed training for teachers to be able to handle research properly. One teacher (Tm2) said: "*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.*"

A chemistry teacher (Tc2) appreciated the emphasis and use of research in teaching STEM to engage learners in active learning and collaboration. The teacher also expressed the need for teachers to be trained on how to handle research in STEM. He said:

> *We also used research projects as a way of guiding learners. Though our training as science teachers at the university had a weak component of research and this created*

a gap in the implementation of STEM education that needed learners to be guided by teachers in research projects.

4.3 Collaborative Teaching in STEM Education

Besides learner-centred teaching methods, the other interdisciplinary nature of STEM education implementation that emerged during data collection was collaborative teaching. When respondents were asked to give information on how they collaborated with each other or other departments to achieve their goals in STEM education, the results showed that STEM education required teachers and departments to work in teams when planning the lessons as one of the new activities that STEM education brought in the field of science education. Teachers indicated that they tapped into other teachers' expertise through continuing professional development (CPDs). One chemistry teacher (Tc1) narrated that:

> *We worked with teachers from other departments such as mathematics and technology. For example, teachers with expertise in computers and technology could come in and help on how we could use ICT tools such as projectors, power points and other gadgets in delivering our lessons and explaining concepts in science. CPDs in lesson planning were done on how best we could handle STEM education.*

The study also revealed that most of the topics that were taught in physics under STEM education, such as heat, were closely related to topics that were taught under practical subjects, such as food and nutrition, and this encouraged the teachers, and departments not to work in isolation but to collaborate with other teachers in the same department or from other departments. One of the strengths that STEM education implementation brought on board was collaborative teaching as observed by a physics teacher (Tp1), who indicated that:

> *If you look at the syllabus for design and technology under STEM education, there is a lot of science there, for example, heat, how heat gets into food, and how a microwave operates. I appreciated how topics in science are linked to other subjects under STEM, and this widens the learners' understanding of concepts. So one of the strengths of STEM education implementation was collaborative teaching.*

A biology teacher (Tb1) said:

> *Biology as a subject area under STEM is linked to other subject areas, for example, the design and technology department uses wood that comes from plants to make chairs, tables, and desks. We had a number of CPDs in planning the lessons with our colleagues in other departments, as STEM was new to all of us, so we needed each other to achieve our goal in STEM education.*

In addition, a teacher (Tm2) from the mathematics department explained that some topics that were found to be common in departments were taught by different teachers from different departments. A teacher could invite another teacher from another department to come in and teach a topic that is common in the two departments. This enabled the teachers to develop a collaborative teaching culture and appreciate the expertise of one another. The teacher further explained that collaborative teaching enabled learners to understand one topic from different perspectives and delivery modes. He said that "*Common topics were taught by teachers from different departments, for instance, when teaching density, calculations of density came from the mathematics side while the actual concept or explanation of density came from science*."

Another mathematics teacher (Tm1) added: "*Once in a while we would share ideas with our colleagues in design and technology, for example, the use of angles from mathematics was used to design a chair or desk under design and technology. In short, we never worked in isolation during STEM education implementation."*

In the area of research, it was apparent that teachers with different expertise collaborated in guiding the learners on research projects. As one chemistry teacher (Tc2) indicated that learners came up with research projects that required input, expert knowledge, and guidance from different departments for the project's goals to be realised. He mentioned that,

> *Some projects that learners came up with needed some knowledge from other departments, such as projects in science that took a quantitative approach (involving numerical values) and needed statistics from the department of mathematics. So, a teacher from the mathematics department would come in and give guidance regarding the statistics in the project the learner was working on*.

4.4 Challenges that were Faced in the Previous STEM Education Implementation

Challenges regarding STEM education implementation were not primarily part of the study objectives. However, challenges that were faced in the previous STEM education implementation emerged during data collection and form a significant part of this presentation of findings. This section presents the findings on the challenges that were faced in the previous STEM education implementation at the selected STEM secondary school as follows:

4.4.1 Inadequate Teaching and Learning Resources for STEM Education

The majority of the respondents mentioned that inadequate teaching and learning resources for STEM education was one the challenges that were faced in the previous STEM education implementation as one respondent, a chemistry teacher (Tc2) narrated:

> *There were no computers for learners to use for research as STEM required learners to research more and make presentations. And some learners were asked to come with their own laptops. Science department has twenty teachers, and all these depended on the two available projectors for lesson delivery.*

A design and Technology teacher (Tdt) also noted that inadequate teaching and learning resources for STEM education was a challenge. He said:

> *We did not have adequate computers, the school only had two computer laboratories that were supposed to be used by science, design and technology and mathematics departments, of course, for our department workshops were there, but outdated and lacked modern machinery for teaching metal work and woodwork.*

Another teacher (Tc1) from the chemistry section said:

> *We lacked chemicals and apparatus in the laboratories, our science laboratories were outdated to be used in the implementation of STEM education. We also did not have computers for research as STEM required us to research more.*

Further, findings revealed that science laboratories that were utilised for science experiments were outdated and could not support the intended STEM education. The picture in Figure 4.3 depicts one of the science laboratories that were utilised for experiments under the implementation of STEM at the selected school.

Figure 4. 3*: Picture of a Science Laboratory*. *Field Data (2023). Photographer: Researcher*

A teacher from mathematics department (Tm2) also mentioned that lack of teaching and learning resources were a challenge in the implementation of STEM education. He said: *"STEM education required a lot of research by both teachers and learners and most schools were not ready to run STEM due to lack of resources such as computers, internet, stocked modern laboratories."*

One head of department said:

> "*We had challenges in internet, computers as we would give assignments to learners that required them to research, but there were not enough computers. Generally, we lacked materials, because, for example, making desks requires money for materials, wood and so on. The status quo of our workshops were not in good condition to fully support STEM education."*

Another head of department said: "*Not enough computers to enable learners to research. Some learners came up with some ideas and needed to do some experiments, we couldn't meet all the requirements needed for these projects due to inadequate resources hence, STEM education remained theoretical."*

4.4.2 Inadequate Training for Teachers in STEM Education

The other challenge that was revealed by the study was inadequate training for teachers to implement STEM education. Teachers needed to be trained in STEM education before it was

implemented. The majority of the respondents agreed that training was given, but only for a week and according to the respondents, training was not adequate for them as one respondent, a biology teacher (Tb2) said:

> *Teachers were not adequately trained to handle STEM education. Teachers should be trained at least for a year and acquire a diploma in STEM education at the established STEM education centres. We were honestly not ready for STEM education; the training just gave us a glimpse of STEM education.*

In addition, a chemistry teacher (Tc2) said: "*personally I didn't get anything because even people who were training us didn't also seem to understand STEM education very well. I must say STEM education implementation was rushed."*

Further, a teacher (Tdt) from Design and Technology Department said: "*Training for teachers in STEM education was not enough and most training sessions were conducted virtually due to COVID-19 pandemic at that time. We were only trained for one week*."

4.4.3 Time consuming

Lesson planning under STEM education was involving and time-consuming as it needed the input of other members of the department or teachers from another related departments and one lesson planning could go for a week as one respondent, a mathematics teacher (Tm2) said that: *"STEM was time-consuming, planning for one lesson took almost the whole week."*

In addition, an administrator mentioned that *"STEM education was somehow time-consuming as lesson plans needed to be done as a team."*

Another teacher (Tm3) added: "We *could not finish the syllabus as the learning process was determined by the learners and some learners were not eligible enough to take STEM."*

Further, one head of department said, *"Time was not enough as the pace of the lesson was determined by the learners, the syllabus was only covered at the pace learners understood the issues in the syllabus."*

4.4.4 Level of difficult in the STEM Syllabi

The other challenge that was faced during the implementation of STEM education was the level of difficult in the STEM syllabus. This affected the pace at which the syllabus was covered because learning and progression to the next topic were determined by the learners.

Findings revealed that some topics in mathematics STEM syllabus were too high in terms of level of difficult for the learners at secondary school. This was evidenced by a mathematics teacher (Tm3) who mentioned that:

> *Mathematics syllabus for STEM was too high for the learners at secondary school level, for example, a 3x3 matrix is by far too high for the learners in Grade ten. We did this topic when we were in the University ourselves. It was too advanced mathematics.*

In addition, a physics teacher (Tp1) indicated that those learners who had weak science and mathematics background at primary school level were disadvantaged as the level of difficult in the STEM syllabus was high. He said, "*STEM was biased and supported only the fast learners, it did not accommodate an average learner."*

A teacher from the biology section (Tb2) pointed out that, "*Some learners were not receptive to the interdisciplinary way of teaching in STEM education. STEM was favouring a certain group of learners, those that are perceived as fast learners."*

4.4.5 Lack of Stakeholders' Involvement in the Implementation of STEM Education

The other challenge that emerged in this study regarding the implementation of the STEM education previously was the lack of stakeholders' engagement at various stages of implementation. Stakeholders such as teachers were not consulted and did not fully understand the direction of STEM education as one respondent, a mathematics teacher (Tm1) mentioned, "*STEM education implementation was rushed; people were not properly consulted, especially the teachers and this didn't help. Most people didn't support the programme."*

In addition, a biology teacher (Tb2) said, *"Teachers were not involved at the planning stage for the programme until it was time for implementation."*

4.5 Research question three: Sustainable STEM Education Implementation

This section presented the findings on the measures that should be considered and put in place for sustainable implementation of STEM education as follows:

4.5.1 Stakeholders in the STEM Education Implementation

With regard to who the respondents viewed as key stakeholders that should be involved at various levels of implementation of STEM education in Zambia, eight stakeholders were

identified. These included; the teachers in schools, parents, industry representatives, university lecturers, curriculum developers, examinations council(s), Government/National Science Centre and learners. When each respondent was asked to mention who they viewed as key stakeholders in the STEM education implementation, teachers were mentioned by the majority of the respondents with the frequency of 9 representing 62%, followed by the parents at the frequency of 6 representing the 46% of the responses, then industries and business representatives at the frequency of 4 representing 31%, while university lecturers, Curriculum Development Centre, Examinations Council of Zambia and National Science Centre were at the frequency of 3 representing 23% and learners at frequency 1 indicating 8% as summarised in Table 4.1.

4. 1: Summary of the Responses of who the Respondents Identified as Key Stakeholders in the STEM Education Implementation

S/N	STAKEHOLDER	FREQUENCY	PERCENTAGE (%)
1	*Schools/Teachers*	8	62%
2	*Parents*	6	46%
3	*Industries*	4	31%
4	*University Lecturers*	3	23%
5	*Curriculum Development Centre*	3	23%
6	*Examinations Council of Zambia*	3	23%
7	*National Science Centre*	3	23%
8	*Learners*	1	8%

Field Data (2023)

4.5.2 Adequate Teaching and Learning Resource Supply in Schools

STEM education requires the schools to be equipped with teachings and learning resources such as computers, science and mathematics laboratories and furnished specialised rooms for practical subjects such as woodwork, metalwork and food and nutrition as one teacher (Tm1) mentioned: "*We needed proper resources allocations, especially science and mathematics laboratories. STEM requires that there are specialised rooms for each subject area."*

In supporting this view regarding the emphasis on the adequate supply of teaching and learning resources for STEM education in schools, a physics teacher (Tp1) added that:

> *Teaching and learning materials should be made available in schools, updated science laboratories (apparatus, there are now digital micrometre screw gauges) are*

needed for STEM education to implemented effectively. In the previous STEM education implementation, looking at laboratory conditions only Edgar Chagwa Lungu STEM secondary school was eligible to offer STEM education.

In addition, a teacher from the biology section (Tb2) also said that *"digital tools such as tablets and computers for teaching and learning are needed in schools."*

A mathematics teacher (Tm2) also added that,

There is no need to rush to implement STEM education as it was the case in the previous STEM education. allow more time for schools to have the needed resources available before implementing the programme. The programme was rushed; no wonder it did not continue as intended.

4.5.3 professional Training for Teachers in STEM Education

Training is one of the key components for any new programme to be successfully implemented. When the respondents were asked to give their views on what training teachers needed, to implement STEM education, a mathematics teacher (Tm1) suggested that "*Adequate training for teachers to handle STEM through workshops, conferences and CPDs so that teachers are involved, and they also air out their views was needed."*

A biology teacher (Tb2) suggested that "*there is need to bring in experts [with full understanding of STEM education] in STEM to take through the teachers in STEM education through CPDs, In-service training or holiday training for STEM teachers."*

It was also noted that training of teachers in STEM education to teach in an interdisciplinary approach is one of the critical areas for the effective implementation of the programme. This was noted by a mathematics teacher (Tm3) who said:

Teachers must be motivated as STEM is not easy as it requires the teachers to work extra. We also need adequate training for teachers in STEM. National Science Centre sent some individuals to Japan for one year-training in STEM, but only gave us one-week virtual training.

4.5.4 Clear Direction, Needs Oriented Curriculum and Implementation Frameworks

For STEM education implementation to be successful and sustainable in future, its direction, intents or goals must be clear to all the stakeholders. The curriculum and implementation frameworks must be in place to guide the implementation process as one respondent, a

mathematics teacher (Tm3) said: *"we were not given proper direction for STEM education. We need proper direction and also resources not us teachers developing teaching aids for our classes."*

On the other hand, with regard to what implementation framework STEM education in schools should take, the results revealed that implementing STEM as a methodology or teaching approach to science and mathematics education was the most outstanding with a few respondents whose view was that STEM education should be implemented as both an approach to teaching and also as content. This was noted from one teacher (Tm2) who responded that,

> *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.*

The view was supported by another teacher (Tm3) who said that *"STEM should be implemented as an approach to teaching mathematics and science, we just encourage more of the use of technology and engineering."*

Further, in giving the perspective of what approach STEM should take in Zambian schools, a teacher from the science department (Tp1) said the following:

> *For me, I still go back to the teaching methods to be 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 so problems. Learners must be able to produce a product after learning some concepts (application) in STEM.*

> *I think STEM education in Zambia can best be implemented through strengthening JETS projects. Every time we have 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.*

A biology teacher (Tb2) added that,

> *STEM should be implemented as a way of teaching, how STEM can be used to enhance the teaching of science is that learners are learning how to think critically. We don't even need to change our 2013 national curriculum, instead, just train teachers to approach the already running curriculum in a STEM way.*

The view was supported by a response from a chemistry teacher (Tc1) who also noted that, **"***STEM can be used as an approach to teaching. The 2013 curriculum must be reviewed to accommodate STEM and incorporate JETS projects in the curriculum for learners to experience real STEM education."*

In addition, one head of department argued that STEM needs to be implemented slowly with specific schools and later, spread to other schools. The head of department added that the approach STEM education should take in Zambian schools is where the learners can learn the theory, do the practical and come up with a product. He suggested as follows:

> *The best approach for STEM I think is where learners do the theoretical part, they do the practice and produce a product (TPP). That way, we will be seeing tangible products even at school level then we can escalate them to commercial levels. We also need a lot of investment in STEM education, so if you spread it throughout the country, you will fail to equip all the schools for learners to experience the actual STEM.*

4.5.5 Opportunities for Future Implementation of STEM Education

When the respondents were asked to give their views about STEM education and future opportunities for its implementation, majority of the respondents welcomed STEM education and mentioned that they were looking forward to STEM education coming back and in a better form. Better form in this context meant putting all the necessary materials in place and getting the schools ready before rolling out STEM education for implementation. The opportunity for sustainable implementation of STEM education lies in the proper dissemination of the information about STEM with a goal of making community members and all stakeholders fully aware of what STEM is all about so that they could support the programme as one respondent, a biology teacher (Tb2) said: *"STEM education is very welcome, but more information needs to be disseminated to the general public about STEM before it can be implemented."*

In addition, a mathematics teacher (Tm1) said:

> *STEM is now the way the world is run, let STEM come back. Most countries have developed because they have embraced STEM. From the onset, let the teachers be involved, as long as teachers continue to be side-lined, STEM will not go anywhere because they will never support its implementation.*

Further, an administrator added that, "*STEM is very welcome; it just needs proper planning before it could be rolled out in schools"*

Another opportunity that could improve the implementation of STEM education in future is proper planning and resources allocation. Planning in this context means putting in place the curriculum, research and clear road map to guide the implementation coupled with stakeholders' constant engagement. One respondent (an administrator) suggested that:

> *The Ministry of Education needs to provide materials and train teachers in these schools that's when STEM will work. For me, STEM was not welcome because I was lacking in terms of materials and equipment, so materials should be provided for me to do STEM education well, not where I start cracking my head. For example, I give the questions to the learners then I start wondering where they were going to get the information and equipment to address the questions.*

A chemistry teachers (Tc1) added that, "*Stakeholders must ensure that school have materials, equipment, specialised rooms, laboratories and well-thought out STEM curriculum before rolling out STEM education to schools."*

In supporting the view that STEM education implementation needs serious planning and resources allocation, another teacher (Tb1) said: "*I personally encourage the government and other major stakeholders to invest in STEM education and allocate more funds on the national budget to STEM education as the idea is so transformative and welcome."*

Further, a teacher (Tp1) from physics sections suggested that "*Government should be fully involved in STEM education implementation and be willing to support projects such as JETS that may come out of STEM schools.*

4.6 Chapter Summary

Findings indicate that STEM education is welcome to the teaching service, because of the quality it brings in education such as linking theory to practice. STEM education focuses on creating a critical, creative and innovative mind in a learner through its constructivist approach and interdisciplinary teaching. Findings also indicate that STEM education has the much needed potential to bridge the gap between education and industry through practical skills development, value addition and innovations. Further, teachers used learner-centred teaching methods such as problem-based teaching, small group discussions, practical scenarios, computer simulations and research to teach STEM. Challenges that were faced in the previous STEM education implementation included among others; lack of teaching and learning materials, inadequate training for teachers to implement STEM education, STEM education being time-consuming as the syllabus was only covered at the pace learners understood the concepts, and lack of stakeholders' involvements. For STEM education to be implemented sustainably, it is required that stakeholders such as teachers are involved from the beginning, there should be adequate teaching and learning material supply in schools, training the teachers in STEM education, clear direction to guide the implementation and massive community sensitisation about STEM education be given so that people understand STEM education and its purpose. Lastly, the study suggested that STEM education should be implemented as a teaching approach that incorporates JETS projects in order for learners to experience real STEM education.

CHAPTER FIVE

DISCUSSION OF FINDINGS

5.0 Overview

This chapter discusses the findings of this study as presented in the previous chapter and how they relate to other studies, science education, theories and practices, in line with the research objectives. The discussion is presented under the following headings: Teachers' understanding of STEM education, interdisciplinary nature of STEM education, challenges faced in the previous STEM education implementation and proposed tentative STEM education implementation framework.

5.1 Teachers' Understanding of STEM Education

When the idea of this study was conceived, it was for the reasoning that little was known about STEM education among teachers and their administrators, hence the question; what are the teachers' understanding of STEM education as the selected STEM secondary school in Lusaka district?

Teachers' understanding and interpretation of STEM education are critical in the implementation of STEM education as teachers are the actual interpreters of the curriculum intents to the learners. A good understanding of the programme [STEM education] by the teachers entails that teachers would plan learning experiences that are in line with the acquisition of knowledge, skills and values projected for in the curriculum. According to the findings of this study, teachers and their administrators, the heads of department and the head teacher viewed STEM education as a learner-centred education approach that embraces a constructivist teaching and learning approach in which the learners are active participants in the learning process and are capable of constructing knowledge (Jamal et al., 2017). Teachers also understood STEM education as an education approach that uses concepts of technology and engineering to link theory and application of scientific and hand-on skills to solve real-life problems. Some respondents viewed STEM education as an education approach to producing a learner who is technology-oriented, analytical and a creative thinker.

In addition, both teachers' and administrators' responses pointed out that in 21st Century with scientific and technological advancements, STEM education is the ideal approach to teaching and learning and that is the way to go if Zambia was to achieve its global competitiveness

and economic development aspirations. These results demonstrate that there is a strong desire among teachers and their administrator to have STEM education in schools.

The findings are in accord with the constructivism learning theory that emphasises on the learner-centred approach and encourages the shift of education from teacher-centred 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, constructivism theory of learning supports the teachers understanding of STEM education that focuses on the use of interdisciplinary approaches in creating analytical, creative and innovative minds in the learners. Effective implementation of STEM education requires that teachers understand what STEM education is, in terms of its purpose, goals and relevance (MoGE, 2020). Thus, teachers' understanding of STEM education entails that their confidence and capacity to plan teaching and learning activities that are in line with the prescribed intentions in the STEM education curriculum are enhanced.

In Zambia, STEM education was introduced 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, teachers viewed STEM education as having the potential of transform science education from a generation of scientific knowledge to one of applying scientific knowledge acquired in solving real-life problems such as the crisis of climate change, unemployment, value addition and agricultural productivity (MoGE, 2020).

The findings align with existing literature in that several studies conducted in different countries indicate the relevance of STEM education in developing human capital for addressing 21st Century challenges that require multi-disciplinary solutions. STEM skills of creativity, innovation, analytical, problem-solving and critical thinking have been identified as imperative to responding to forces of globalisation and fourth industrial revolution (Mpofu, 2020). Thus, teachers' understanding of STEM education and use of constructivist teaching methods in line with the relevance of STEM education to producing 21st Century skills in the learners are critical in the implementation of STEM education in schools.

5.2 Interdisciplinary Nature of STEM Education

STEM education emphasises on interdisciplinary approach to teaching and learning where the successful delivery of every lesson in any of the four disciplines of STEM requires tapping into the expertise of the three other disciplines to produce conceptual understanding in the learners. It also follows a constructivism teaching approach that places the learners at the centre of the teaching and learning process (Diana & Sukma, 2021). The strength and success of STEM education implementation lie in the teachers' competencies to select and use appropriate teaching methods to deliver the curriculum intentions. Thus in addressing research question number two, that sought to establish the teaching methods that teachers were using to implement STEM education at the selected school, some of the teaching methods that were identified included problem-based teaching and learning, small group discussions, practical scenarios and research.

5.2.1 Problem-based Teaching and Learning

STEM education engages learners in the education that is focused on solving problems that societies face and so every lesson delivered in a STEM subject at the selected school was presented in form of a problem such that learners could figure out solutions to a problem on their own.

Results indicated that teachers used problem-based learning methods where they planned and presented the lessons in form of an open-ended problem and allowed learners to figure out ways of arriving at the solution to the problem using scientific and mathematical concepts. Learners were expected to work in small groups, discuss, debate, collaborate until conclusions and solutions to an open-ended trigger problem were found. The findings are in accord 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 activities that foster analytical and critical-thinking skills in the learners.

The findings also speak to what the government of Zambia is striving to achieve. The government's efforts to implement STEM education are driven by the desire to produce learners who are self-motivated, creative, confident and productive individuals, who are holistic, independent learners with values, skills, and knowledge to enable them to succeed in life (Magasu, Mutale & Gondwe, 2022). Therefore, the use of inquiry methods such problem-based learning by teacher at the selected school indicated that there was conformity to the teaching methods that were recommended in the STEM education curriculum (MoGE, 2020).

This implication is that teachers would plan lesson activities that support the STEM education goals and implemented STEM with an understanding of appropriate teaching methods that suit the interdisciplinary teaching of STEM.

5.2.2 Practical Scenarios

The other teaching method that teachers were using in the previous STEM education implementation was the use of practical scenarios. According to Muhamad, Zaman and Ahmad (2012), scenario-based learning when incorporated in the system to enhance teaching and learning, has shown to be a progressive approach in promoting critical thinking in the learners.

The findings indicated that teachers planned each lesson in relation to a practical scenario that learners could easily relate to and apply scientific thought to, in order to construct meaning. For instance, in teaching about *fractional distillation*, a topic in chemistry, a teacher would bring a practical scenario such as brewing of *Kachasu* [a locally produced traditional beer]. The ethanol in kachasu could also be used at a commercial level in industries to manufacture cleaning agents, hand sanitisers and other domestic products. The process of producing *kachasu* uses scientific procedures such as fractional distillation, which local people in some parts of Zambia have just mastered without learning them formerly in schools and use them to brew *kachasu* for business.

It is noted that STEM education implementation embraces such close connections between theory and practice, where learners are able to acquire scientific knowledge and skills through practical realities that they can relate to. In addition, application of scientific concepts such as fractional distillation in brewing '*kachasu'* indicate that there is already evidence of real STEM indirectly going on in the communities where the learners come from. Thus, bringing such practical realities to the classroom set up through learner-centred teaching methods in the implementation of STEM education allows learners to appreciate science and its connection with the real-world, which the is focus of STEM education.

Therefore, the government takes advantage of the situation by implementing STEM in schools so that the same economic activities that people engage in, on a daily basis in the communities could be formalised in the education system to empower current and future generation with innovative and creative minds to feed into the sustainable economic development goals for Zambia (MoGE, 2020). In addition, commercialising these STEM economic-related activities through the implementation STEM education, would help in

enhancing the informal employment sector and create jobs for the Zambian youths (Mukosa et al., 2020).

Further, the findings of the current study revealed that teachers also used computer simulations such as PhEt-simulations and videos in teaching some topics that seemed abstract to the learners and that could not be presented in a local practical situation. The findings indicated that the technology [T] part of STEM was covered in such a way that teachers incorporated computer simulations, videos and links in teaching subjects under STEM. Further, respondents indicated that the use of practical scenarios and simulations provided the sense of shift from the traditional teaching approach to STEM teaching, which embraced the constructivist approach, and this made the teachers to appreciate the transformative approach of science and technology education imbedded in the STEM education programme.

5.2.3 Research

The other method that teachers used in the previous STEM education implementation was research, to strengthen learners' involvement in the teaching and learning process. According to the findings of this study, the research component in STEM education added a certain quality to science and mathematics education that was not common in the traditional non-STEM teaching methodologies. Through the use of research as one of the teaching methods to enhance learner's active engagement in the learning process, learners were expected to be exposed to the research process at an early stage such as secondary school so that scientific investigation skills are built in the learners while in secondary schools to create a strong base for scientific inquiry and career choices.

The findings are in line with MoGE (2019), which indicated that research is one of the ways of enhancing the learners' ability to apply scientific inquiry through identifying of problems, making hypothesis, designing a research, interpreting and analysing data and presenting the findings. Therefore, exposing learners to the research process at an early stage creates a strong foundation in research and use of scientific inquiry in problem-solving. The implication of incorporating research in the teaching of STEM is that there is conformity to the intentions of STEM education to produce learners who are critical thinkers are able to relate their thinking to solving real-life problems such as the crisis of climate change and value addition. Learners are expected to graduate from school or training at any level of education with the ability to identify problems that society is facing and use the scientific research procedures [research] to find solutions to the problems, as such they are perceived as

problem-solvers. This is in line with the goals STEM education, to produce to society individuals who are critical, analytical and use scientific investigation to solve problems in their environmental and social economic settings (MoGE, 2018).

The respondents noted that the emphasis for strengthening research in STEM education was received with great enthusiasm as they pointed out that research component in secondary school teaching had the potential to produce the kind of a learners they desired. Therefore, it is indeed accepted that a citizenry with a strong capacity in research has a high likelihood of scoring high in terms of innovations, scientific skills development and national economic development (GRZ, 2017). Learning from countries such as China, Singapore, Russia with high Gross Domestic Product (GDP) and several other large economies, Zambia has also embraced STEM education as one way of achieving its national developmental aspirations particularly targeting the young people who are the masses, to carry on with the long-term vision for Zambia as enshrined in the Seventh National Development Plan (GRZ, 2017). Therefore, the use of research in the implementation of STEM education indicated that there was an understanding of appropriate teaching methods and adherence to the teaching methods recommended in the STEM curriculum.

5.2.4 Collaborative Work Culture in STEM Education

In addition to the learner-centred teaching methods, the other important component of the of the interdisciplinary nature of STEM education implementation is the collaborative work culture among the teachers. It was noted in this study that before STEM education was implemented, most science-based teachers worked in isolation either as mathematics teachers or science teachers and this was also the same with other departments, which worked in isolation. However, the quality that STEM education implementation brings to the science education is the school culture that promotes collaborations among teachers and departments for the common goal of producing a holistic learner. This is in line with Hug and Wurdinger (2007) who noted that knowledge is socially constructed and view the school as a social environment where teachers and learners can work together in collaboration to achieve the intended goals.

Collaboration in this context means that successful teaching of each of the four disciplines of STEM requires that teachers or departments tap into the expertise of other teachers from the same or related departments. For instance, learners maybe working on a quantitative research project in science, the project may require some knowledge and guidance in statistics from

mathematics discipline to ensure that the project achieves its objectives. In this case, collaboration among teachers of different expertise becomes very important in producing and shaping the desired competencies and attitudes in the learners and implementation of STEM education at school level supports such collaborations aimed at improving the quality of education in schools.

Therefore, findings of the current study indicated that the successful implementation of STEM education depends on the teaching methods that teachers use in delivering the lessons. Teachers indicated the teaching methods in the rationale section of their lesson plans, the teaching methods included; problem-solving, inquiry, experimentation, field trip and projects as recommended in the STEM education curriculum. The results on the teaching methods that teachers were using to teach STEM suggested that there were efforts by teachers in planning what was to be taught and learnt in line with STEM curriculum intentions. However, according MoGE (2020), some teachers indicated question and answer, and discussion as teaching methods when in principle, these are not teaching methods. This implied that lessons would not be delivered in line with STEM education curriculum intentions. Thus, a detailed rationale in STEM education implementation is an indication that the teacher has understood the curriculum intentions and is likely to interpret them correctly through lesson delivery.

5.3 Challenges Faced in the Previous STEM Education Implementation

With regard to the challenges teachers and their administrators faced in the implementation of the previous STEM education, it was observed that in as much as STEM education was a progressive programme in promoting meaningful science and mathematics education, its implementation came with challenges that included; inadequate teaching and learning materials, inadequate training for teachers, time-consuming and lack of key stakeholders' involvement at various stages of the programme.

5.3.1 Inadequate Teaching and Learning Materials

One of the challenges that were faced in the previous STEM implementation was inadequate teaching and learning materials. The study indicated that STEM was implemented in selected secondary schools at the time schools did not have adequate materials such as textbooks, computers, internet connectivity, modern science laboratories and other specialised rooms needed for the effective implementation of STEM education. In addition, STEM education required that learners engage in research and this part needed computers and internet

connection, which were in short supply in the schools. The study indicated that sharing the few computers that were available in the computer science laboratory was a challenge.

For science subjects that required experiments, the laboratories that were available did not have apparatus and chemicals to fully support STEM education. The findings are in conformity with the view of Ejiwale (2013) who argued that inadequate teaching and learning facilities have weakened STEM education implementation at all levels of education. Ejiwale (2013) observed that, most schools are not equipped with instructional facilities needed for STEM education implementation. The current study also revealed that in the department of design and technology, machinery for hands on activities were there, but they were old and outdated. This is in line with the study by MoGE (2020) on the assessment of STEM education implementation in schools. The study revealed that teachers indicated the teaching materials they consulted, in the lesson plans, however, most of the teaching materials indicated were limited and not appropriate. Of the materials indicated, there were only printout materials such as textbooks. In addition, there were no electronic books indicated to have been consulted.

The reason for limited teaching materials indicated in the lessons plans could have been the limited access to appropriate teaching materials. There was also no indication of electronic books in the lesson plans, this could be attributed to lack of internet connection and ICT skills by teachers to access e-books (MoGE, 2020). The implication is that the lack of appropriate STEM teaching material would impede the achievement of STEM education implementation goals. In addition, professional development activities should not only enhance teachers' pedagogical content knowledge, but also include enhancement of teacher's basic ICT skills and ability to be resourceful for improved STEM education implementation. Therefore, the results suggested that improved and sustainable STEM education implementation requires a good supply and allocation of teaching and learning resources before implementing the programme.

5.3.2 Inadequate Training for Teachers in STEM and Stakeholders Involvement

The other challenge that was faced in the previous STEM implementation was the lack of training for teachers to implement STEM education with confidence. The findings revealed that preliminary training was provided, however, it was only one week of training and the trainers were not experts in STEM education. Adequate professional development activities involving experts in STEM education is one of the key components of capacity-building for

implementation of STEM education (Polgampala & Huang, 2017). This view is in line with the view of Jong, Song, Soloway and Norris (2021) who argued that many innovative educational reforms have failed because the programmes have not helped the teachers to build their capacity and competencies to implement the reforms.

In the Zambian context, teacher training programmes are designed in such a way that a science-based teacher is trained in one or two STEM fields, hence, teaching a subject using knowledge and expertise from the three other disciplines requires extra professional training in terms of planning the lessons, teaching strategies and capacity to incorporate engineering [E] and technology [T] components of STEM in teaching other subjects. The results suggested that teacher professional training programmes in STEM fields could be improved through strengthening continuing professional development (CPDs), seminars, conferences and workshop aimed at building the capacity and competencies of teachers to teach STEM in an interdisciplinary manner. The implication is that there would enhanced levels of confidence in the implementation process and conformity to the STEM education curriculum intentions.

On the other hand, the previous STEM education implementation could not continue as intended partly because of lack of key stakeholders' involvement in the development and implementation of the programme. Findings revealed that some key stakeholders were not involved in the programme. The results suggested that successful implementation of any educational programme requires wide consultations, trainings and stakeholders' involvement at various levels. In addition, STEM education as a programme is an interdisciplinary approach that achieves its goals through involvement of expertise from different disciplines. Hence, engagement of stakeholders' in the development and implementation of STEM education are critical for the improved STEM education.

The study identified the university lecturers, teachers, curriculum developers, examinations council, industry and business representatives, parents and learners as key stakeholders in the implementation of STEM education. Thus the results suggested that, universities and university lecturers' involvement in STEM education is key in enhancing the quality of training programmes for teachers in STEM, providing necessary expertise, guidance and research in order for STEM to be implemented in its real sense.

5.3.3 Time-consuming

The other challenge that was faced in the previous STEM education implementation was the time aspect. The implementation of STEM education at classroom level was highly involving and time-consuming as the lessons and syllabi could only be covered at the pace learners understood the material and the teacher could not proceed to the next topic, until this was achieved. This led to the failure to complete the syllabi and schemes of work as learners determined the pace of the teaching and learning process. In addition, it was observed that the implementation of STEM education was time-consuming as lesson planning for one lesson could take a week or two because it needed input of other teachers and departments through section conferences or CPDs to plan the lessons.

This entails that coordinating all teachers teaching a particular subject and coming to a common conclusion for the lesson plan to be approved was a challenge and needed a lot of time. However, one of the memorable experiences that teachers had during the implementation of STEM was that the delivery of lessons was easy because the learners took the centre stage in the teaching and learning process. This is in line with the purpose of this study and the constructivism theory of learning that successful implementation of STEM education focuses on the active engagement of the learners in the learning process. The other memorable experience that emerged in this study was the opportunity that STEM education provided to the learners, to have experiential learning, research, debate findings and present their findings. This made both learners and teachers appreciate science as a way of life and as a way of solving problems.

5.4 Proposed Tentative STEM Education Implementation Framework

For STEM education programme to be implemented successfully in schools, it is necessary that its vision, curriculum, context and implementation approach are made clear in order to guide the implementation process. Literature indicates that every education reform must be understood by stakeholders in terms of relevance and value (Chiu, Price & Ovrahim, 2015).

The findings of this study were centred around teachers' understanding of STEM education, the interdisciplinary nature of STEM education, the challenges that were faced in the previous STEM education implementation and how these challenges would inform the future implementation of STEM education in Zambia. In addressing the research question number three, the study recognised the importance of the implementation framework for improving STEM education implementation in Zambian schools.

It is also noted that even though STEM education is widely regarded as an innovative and progressive education programme, each country has implemented it differently and in the context of its local needs and demands. For instance, a synthesis of literature indicated STEM education in Indonesia has been implemented in secondary schools through project-based learning model (Permanasari, Rubini & Nugroho, 2021), while in Rwanda, it has been implemented at university level in form of STEM projects with emphasis on the use of local technologies to produce local products and services (Lwakabamba & Lujara, 2003).

Findings of this study showed that STEM education in Zambia should be implemented as an approach to teaching and learning as opposed to content. This suggests that STEM could still be incorporated into the mainstream national curriculum of 2013 as a methodology with more emphasis on the production and use of scientific and technological skills, values and attitudes to solve problems such as the crisis of climate change (Magasu, Mutale & Gondwe, 2022). In addition, the findings indicated that STEM education should promote school projects that lead to the production of tangible products and application of the scientific and engineering competencies to solve real-life problems.

In projects aimed at identifying problems and finding solutions to the local problems such as climate change, agriculture, loss of biodiversity and means of production, learners gain motivation to engage in learning experiences that are appealing to the real-life situations they easily relate to (Kaing, 2016). The implication is that the progressive principles imbedded in STEM in line with the national developmental aspirations would be introduced to equip learners with skills and values needed for them to grow into responsible citizens, productive and problem solvers (GRZ, 2017). Thus, the results suggested that teachers and their administrators are yearning to see that STEM education takes root in Zambian schools. This is also seen in the government's efforts to implement STEM education. According to (Mwale, Moonga & Banda, 2020), there has been a growing attention to STEM education in terms of policies, legal frameworks, curriculum reforms and several other STEM related activities in the education arena.

However, results suggested that the curriculum reforms, policy directions and implementation frameworks on STEM education in Zambia must be anchored on the local needs and context. As can be observed from the literature reviewed that there are commonalities in STEM education across the globe, in terms of STEM's vision, relevance and purpose, but every country has implemented STEM education differently based on the local context and needs.

In addition, results suggest that STEM education in its original format, is foreign to the Zambian context. Hence, if it has to be effective and significant to the Zambian learners, communities, industry and economic development goals, there is a need to re-contextualise it so that it aligns and reflects the Zambia context in terms of vision, relevance and implementation approaches.

Therefore, to respond to the third research question in relation to sustainable implementation of STEM education in the Zambian context, this study suggests that Junior Engineers, Technicians and Scientists (JETS) projects be formalised and incorporated into the national curriculum of 2013 to form a tentative STEM education implementation framework in Zambian schools. Incorporating JETS projects into the national curriculum would improve the implementation of STEM education and strengthen the application of the knowledge and skills needed to address various problems that local communities face. Mwale, Moonga and Banda (2020) claim that living in a global village entails co-existence and collaborations achieve common goals. It is from this point that Zambia focused on reviewing it school curriculum making it knowledge, skills and values (KSV) compliant and STEM education becomes a pillar to strengthen Zambia's competitiveness.

Thus, a tentative implementation framework for STEM education that strengthens JETS projects in Zambian schools is 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). The proposed implementation framework is also in line with the constructivism theory of learning that underpins this study based on the assumptions that an education of relevance engages learners in learning experiences that allow them construct knowledge through collaborations and interaction with the real world (Diana & Sukma, 2021).

Further, formalising and supporting JETS projects in schools through STEM education implementation and approaching them from constructivist perspectives have the potential to make the Zambian education sector implement real STEM education that will not only make schools to be learning institutions, but also avenues of production to contribute to national sustainable development as school will produce products that could be sold on the markets or utilised by households. As Zambia strives to provide an education that will enhance productivity in disciplines such as agriculture, mines, technology and tourism and also

application of scientific and engineering skills to solve social, economic and environmental problems, context-based JETS projects incorporated into STEM education forms a progressive implementation approach for STEM education.

In addition, project-based learning such as JETS enhance 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 review of literature, it was observed that most implementation frameworks such as the project-based learning (PjBL) framework in the case of Indonesia, emphasised projects to be critical in the implementation of STEM education because of the interplay among scientific knowledge acquisition, application of scientific and engineering skills and products.

Through a critical synthesis of a study by Permanasari, Rubini and Nugroho (2021) which indicated that STEM education in Indonesia was implemented in form of Projects and that learners produced tangible products, it can be argued that without JETS projects being incorporated into STEM education to form the basis for improved STEM education implementation in Zambia, sustainable STEM education implementation goals will not be achieved.

In addition, through the literature review and learning from other education systems, it was observed that progressive STEM education implementation frameworks that embrace project-based learning are the 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 to form a tentative implementation framework to improve the implementation of STEM education in relation to the local community needs and national developmental agenda.

It is also noted that exhibitions of JETS projects by schools during the Zambia National Trade Fair attract a lot international viewers and partners across the globe (Sanches, 2020). This in itself is an indication that there is potential for analytical thinking and creativity in the Zambian learners that need deliberate motivation and support, to take up STEM career pathways. Thus, the Ministry of General Education could take advantage of these creative minds to re-build and improve the Zambian education system through the JETS-STEM integration implementation framework for national sustainable development.

Lastly, the study envisions real youth empowerment and real gross domestic product through the implementation of STEM education embedded with JETS projects. Implementing STEM education by promoting JETS projects where learners in schools learn theory and apply the theoretical concepts to design projects and produce tangible products is likely to improve STEM education implementation in the context of local community needs and Zambia's competitiveness at both regional and global levels.

5.5 Chapter Summary

This chapter interpreted and discussed the research findings as presented in the previous chapter. The chapter discussed the findings centred around the teachers' understanding of STEM education, interdisciplinary nature of STEM education, challenges faced in the previous STEM education implementation and implementation frameworks for Sustainable STEM education.

Teachers' understanding of STEM education is critical in the implementation of STEM education as teachers' understanding entails that the teaching and learning activities would be planned in line with the curriculum intended goal. Active and transactional teaching methods such as problem-based learning, inquiry, experiments, projects, practical scenarios, collaborative learning and research as key teaching methods in achieving STEM education goals. These teaching methods are also emphasised by the constructivism learning theory because of them being learner-centred teaching methods. The chapter further discussed the challenges that were faced in the previous STEM education implementation such as inadequate teaching and learning materials, inadequate computers for research, lack of key stakeholders' involvement and professional training for teachers in STEM education.

Finally, the chapter discussed the tentative implementation framework for STEM education to be adopted. The study proposed a tentative implementation framework that incorporates JETS into the national school curriculum for improved and sustainable STEM education implementation in future.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.0 Overview

This chapter presented the conclusion and recommendations of the study. The study had set out to establish the insights into the implementation of STEM education at a selected STEM secondary school in Lusaka and makes a conclusion in line with the research objectives. The chapter ends with the presentations of the recommendations for improvement in the implementation of STEM education and implications for further research.

6.1 Conclusion

The findings of this study on the insights into the implementation of STEM education at a selected STEM secondary school indicated that teachers viewed STEM education as a learner-centred education approach that uses concepts of technology and engineering to link theory and application of scientific and hand-on skills to solve real-life problems. Some respondents viewed STEM education as an education approach to producing a learner who is technology-oriented, analytical and a creative thinker.

Some of the challenges that were faced during the previous STEM implementation as emerged during this study included inadequate teaching and learning materials such as computers, updated science and mathematics laboratories, specialised rooms and modern equipment for the practical subjects under STEM, inadequate professional training for teachers to enhance their competences to implement STEM and inadequate key stakeholders' involvement in the implementation of the programme [STEM]. Due to these challenges in implementation, it was difficult for the teachers to shift from the traditional way of teaching to the constructivist way of teaching as recommended in the STEM curriculum, making it difficult for teachers and learners to experience real STEM that they had anticipated. The implication is that STEM education would not have yielded the intended outcomes in the midst of these challenges.

The study further concluded that the teaching methods that teachers were using in teaching STEM such as the inquiry, problem-based learning, scenarios, projects, field trips and research were in line with the teaching methods recommended in STEM curriculum.

Problem-based learning, inquiry and research were the most common methods that were used by majority of teachers. This indicates the conformity to the STEM education curriculum guideline for implementation and commitment to the achievement of STEM education goals.

However, some teachers, indicated that they used, discussion and question and answer as teaching methods. This indicated that some teachers had a challenge distinguishing teaching methods from strategies as discussion and question and answer are not teaching methods, but strategies that could be found in any teaching method (MoGE, 2020). The implication is that lessons would not be planned and delivered in line with STEM education curriculum, hence impeding the achievement of STEM education goals. Therefore, there is need to strengthen the professional development activities among teachers to enhance their capacity to use appropriate teaching methods in STEM education.

Further, the study proposed a tentative STEM education implementation framework in which JETS projects are to be enhanced and integrated into the national curriculum of 2013 for improved and sustainable STEM education implementation.

Thus, this study did not focus on the reasons why the programme [STEM] failed to continue as intended, but focused on establishing previous experiences and what the implementers' views were for improved STEM education implementation in future. Learning from those experiences and the views of the implementers would create a strong basis for recommendations of improved and sustainable STEM education implementation in future.

6.2 Recommendations

In view of the findings of this study, the following recommendations are made:

1. Government should allocate more funds towards developing adequate STEM teaching and learning materials. This recommendation arises from the findings that one of the major challenges faced during the previous STEM education implementation was the inadequate teaching and learning materials needed for the intended STEM education.

2. STEM education should be implemented in the form of JETS projects imbedded in the mainstream 2013 curriculum. The recommendation arises from the findings on whether STEM is to be implemented as a teaching approach or as content. The findings indicated that there is no need for changing the curriculum or having two parallel curricula, but using the same 2013 curriculum, embrace JETS projects in

schools to instil engineering, technical and scientific skills in the learners at an early stage and STEM education will be experienced that way in the Zambian context as the whole science education system will aim at producing engineers and scientists that can contribute to industrialisation and sustainable economic development.

3. The Ministry of General Education should create more avenues for collaboration and partnerships with local industries so that career pathways and directions for the needed skills are clear to the learners when they are still at secondary school. The recommendation arises from the responses that majority of the participants indicated our education system has not been able to address the human resource needs of the local industries for sustainable development and job creation among the youths. Creation of the collaborations and partnerships between schools and industries and other STEM related agencies through internships, field trips to the actual industries such as copper mines, textile, processing plants would bridge the gap that exists between what schools are producing and what the demands of workforce are.

4. There is need to involve all key stakeholders at various levels of STEM education implementation to create a sense of ownership for the programme. The recommendation arises from the findings that STEM education did not continue as intended partly because some key stakeholders such as teachers were not involved.

6.3 Implications for Further Research

It is evident from this study that STEM education is broad and further elaborative studies need to be carried out. The following are some of the recommendations for further research:

1. There is need for a research on the models of implementing STEM education that could be adopted in Zambia. This may help to make STEM education serve its purpose as a tool for sustainable economic development.

2. There is need for a study to assess the effectiveness of the proposed tentative STEM education implementation framework on a large scale. This arises from the views that STEM education should incorporate JETS projects and produce tangible products. The proposed tentative STEM education implementation framework could be tested for effectiveness on a large scale involving all secondary schools in Zambia.

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APPENDICES

Appendix 1: Individual Letter of Consent

Research topic: Insights into the implementation of STEM education. A study of a selected STEM secondary school in Lusaka district.

Dear participant,

This consent form serves to give you an understanding of the purpose of this research and subsequently the procedure to follow when undertaking it. Implications for your participation are explained. Make sure you read the information carefully, or that it has been explained to your satisfaction.

1. **Description**

This study is purely an education research. The researcher is a student at the University of Zambia pursuing a Master of Education degree in Science education. This research is a major requirement for the researcher to complete this programme.

2. **Purpose**

The researcher wishes to establish the teacher's experiences and views on STEM teaching in secondary schools in Zambia.

3. **Consent**

Participation in this activity is voluntary, i.e. you are free to object to participation.

4. **Confidentiality**

All the data collected from this research will be treated with utmost confidentiality.
Participants are assured of anonymity in this research.

5. **Rights of participants**

The rights of the participants will be protected and respected. Participants are assured that they shall not suffer any harm as a result of participating in this exercise. Participants are free to ask for clarification at any point of the exercise and to inform the researcher if they feel uncomfortable about any procedure in the research.

6. **Declaration of Consent**

I have read and fully understand this document. I, therefore, agree to participate in this exercise.

Signature…… **Date…….**

Appendix 2: Semi-structured Interview Guide for Teachers

The University of Zambia, School of Education Department of Mathematics and Science Education.

Topic: Insights into the implementation of STEM education. A study of a selected STEM secondary school in Lusaka district.

(i). Opening Protocols.

(ii). Ice Breakers

(a) Sex [ ]

(b) University attended …….

(c) Qualification obtained ……....

(d) Age ……

(e) Years of experience in teaching ……

(f) Number of schools taught at…….

(iii). Questions.

1. How do you understand the concept of STEM Education?
2. How does your earlier training and experience as a science teacher align with the interdisciplinary nature and demands of STEM education?
3. What change do you think STEM education would bring to Zambia in terms of linking science education to industry? (focusing on value addition and job creation).
4. What teaching methods/approaches were you using in teaching STEM subjects especially that STEM requires you to teach Science using multiple academic fields of knowledge?
5. How were your teaching methods in STEM subjects relating to the goals of STEM such as job creation, value addition, critical thinking, innovation and entrepreneurship?
6. Briefly, describe how you tapped into the expertise of other teachers from Design and Technology subjects to support your science lessons.
7. What are some of the challenges that you faced in implementing STEM in your classroom(s)?
8. Who would you consider to be key stakeholders in the implementation of STEM education in Zambia?
9. What are some of the things you think are needed in schools for effective implementation of STEM education?

10. If STEM is to be the route for sustainable science education in Zambia and serve its purpose for job creation, value addition to the natural resources, innovation and entrepreneurship, how do you think STEM should be taught/implemented in schools?
11. What were your memorable or best experiences when implementing STEM education?
12. Any other comments/views you would like to share with regard to the future and effective implementation of STEM education in Zambia?

Appendix 3: Semi-structured Interview Guide for Heads of Departments

The University of Zambia, School of Education Department of Mathematics and Science Education.

Topic: Insights into the implementation of STEM education. A study of a selected STEM secondary school in Lusaka district.

(i). Opening Protocols.

(ii). Ice Breakers

(a) Sex [ ]

(b) University attended …….

(c) Qualification obtained ……....

(d) Age ……

(e) Years of experience as H.O.D ……

(f) Number of schools taught at…….

(iii). Questions.

1. How do you understand the concept of STEM Education in the science education?
2. In what ways do you think STEM would transform science education system in Zambia?
3. As head of department, what are some of the things that your department did differently in implementing STEM in line with the STEM goals such as critical thinking, value addition, transferring of entrepreneurship skills and job creation?
4. What teaching methods, techniques, strategies or approaches did your department employ to teach STEM since it required tapping into other departments' expertise and how did those teaching methods help in achieving the STEM outcomes?
5. What projects or finished products did your department produce under the implementation of STEM education?
6. What are some of the challenges that you faced in implementing STEM as a department?
7. Who would you consider to be key stakeholders in the implementation of STEM education in Zambia?
8. What are some of the things you think should be put in place in Zambian schools for effective implementation of STEM education?
9. What best practices were implemented in the previous STEM education programme?
10. If STEM is to be the route for sustainable science education in Zambia and serve its purpose for job creation, value addition to the natural resources, innovation and

entrepreneurship, how do you think STEM should be taught/implemented in the Zambian schools?

11. Any other comments/views you would like to share with regard to the future and effective implementation of STEM education in Zambia?

Appendix 4: Semi-structured Interview Guide for the Head Teacher

The University of Zambia, School of Education Department of Mathematics and Science Education.

Topic: Insights into the implementation of STEM teaching. A study of a selected STEM secondary school in Lusaka district.

(i). Opening Protocols.

(ii). Ice Breakers

(a) Sex [ ]

(b) University attended …….

(c) Qualification obtained ……....

(d) Age ……

(e) Years of experience as Head teacher……

(f) Number of schools taught at…….

(iii). Research Questions.

1. How do you understand the concept of STEM Education in science education?
2. In what ways do you think STEM is relevant to science education system and industry in Zambia?
3. What are some of the skills, products and innovations did your school produce as result of STEM implementation?
4. In what ways did your administration support the Heads of departments and teachers in the implementation of STEM?
5. What are some of the challenges that your school faced in implementing STEM?
6. If STEM is to be the route for sustainable education in Zambia and serve its purpose for job creation, value addition to the natural resources, innovation and entrepreneurship, what approach do you think STEM implementation should take in Zambian schools?
7. What best practices and values for effective implementation of STEM would you like to see in Zambian schools?
8. Any other comments/views you would like to share with regard to the future and effective implementation of STEM education in Zambia?

Appendix 5: Permission Letter

The District Education Board Secretary,

Ministry of General Education,

P.O Box, 50297, Lusaka.

April, 2023

Christopher Haamasama

University of Zambia,

Department of mathematics and sciences

P.O Box 32379, Lusaka.

Dear Sir/Madam,

RE: PERMISSION TO CONDUCT A STUDY AND COLLECT DATA FROM A SELECTED STEM SCHOOL IN LUSAKA DISTRICT

Refer to the above subject matter. I am a student at the University of Zambia pursuing a Master's Degree in Science education. I am currently conducting a research on STEM Education under the title: The insights in the implementation of STEM teaching. A study of a selected STEM secondary school in Lusaka district. The target population for my proposed study are teachers teaching STEM subjects and their Administrators. I am preparing for data collection for my study and therefore seek permission through your office to enable me collect Data from the selected STEM secondary school in Lusaka.

Thanking you in advance

Yours sincerely

Christopher Haamasama - 2019100975

Appendix 6: Proposed Research Budget

S/N	DESCRIPTION	QUANTITY	UNITY PRICE (ZMW)	TOTAL COST (ZMW)
1	**Stationery**			
	- Reams of paper	03	90	160
	- Box of pens	01	30	30
	- Flash disk 4GB	01	75	75
2	**Research equipment**			
	-Typing proposal and report	08	200	1600
	-Printing: copies of proposal and Report.	08	200	1600
	- Binding: copies of proposal and report	08	100	800
	- Communication processes (airtime)	-	600	600
4	**Research cost**			
	- Transport	-	-	1440
	- Feeding per day	14	80	1120
5	- Ethical clearance	01	500	500
5	**Miscellaneous**			800
6	**GRAND TOTAL**			**K8,725**

Appendix 7: Proposed Work Plan and Timetable

S/N	ACTIVITY DETAILS	DATES	DURATION
1	Preparation of research proposal	November - December, 2022	Eight weeks
2	Development recasting of data collection instruments	January, 2023	Three weeks
3	Data collection, processing and analysis	June, 2023	one week
4	Report writing, typing and editing , proof reading, production and submission of first draft	June, 2024	Four weeks
5	Refining and submission of final draft	October, 2024	Four weeks

Appendix 8: Ethical clearance

THE UNIVERSITY OF ZAMBIA
HUMANITIES AND SOCIALSCIENCES RESEARCH ETHICS COMMITTEE

REF NUMBER: HSSREC: 2022-DEC-013

PROGRAMME: MASTERS

PROJECT: LOCAL

STUDY TITLE: INSIGHTS INTO THE IMPLEMENTATION OF STEM TEACHING: A STUDY OF A SELECTED STEM SCHOOL IN LUSAKA DISTRICT

PRINCIPAL INVESTIGATOR (PI): CHRISTOPHER HAAMASAMA

OTHER INVESTIGATORS: NIL

SUPERVISOR: DR NACHIYUNDE KABUNGA

CO-SUPERVISOR: NIL

1. **TITLE (Is it clear?)**
   Are there ethical issues ❑Yes ☒ No

   Clear.

2. **STATEMENT OF PROBLEM (Is the problem clear / Has it come out?)**
   Are there ethical issues? ❑Yes ☒ No

   Problem has been described clearly.

3. **PURPOSE OF THE STUDY (Is it clear?)**
   Are there ethical issues? ❑Yes ☒ No
4. **S**

   Clear.

   E
   CIFIC OBJECTIVES (Are they clear?)
   Are there ethical issues? ❑Yes ☒ No

5. Clear.

   E

SEARCH QUESTIONS (Are they clear?)
Are there ethical issues? ❑Yes ☒ No

Clear.

6. **SIGNIFICANCE OF THE STUDY (Is it clear?)**
Are there ethical issues? ❑Yes ☒ No

Clear.

7. **LITERATURE REVIEW (Has there been a critical analysis to help establish the gap, to help show the value addition of the current study?)**
Are there ethical issues? ❑Yes ☒ No

The literature review is satisfactory though too descriptive in some sections.

8. **METHODOLOGY**

(i) Research Design (Is it clear?)

Are there ethical issues? ❑Yes ☒ No

Clear.

(ii) Sample and sampling procedure (Is the scientific rigour being followed?)

Are there ethical issues? ❑Yes ☒ No

Satisfactory.

(iii) Data collection procedure (Are they being followed without defaulting on the ethics?)
Are there ethical issues? ❑Yes ☒ No

To be followed without any ethical issues.

(iv) Data analysis (Is it acceptable?)
Are there ethical issues? ❑Yes ☒ No

Acceptable

9. **RESEARCH INTRUMENTS (Are they in line with the design and research methods?)**

Are there ethical issues? ❑Yes ☒ No

The selected instruments are line with the research design and method.

10. **HICAL CONSDERATIONS (Have all the ethical considerations been followed so that all the participants are protected?)**

Are there ethical issues? ❑Yes ☒No

Ethical issues have been covered and given full attention in this protocol.

11. **VERDICT**

What is the verdict for this study?

Approved☒ Approved subject to corrections❑ Rejected ❑

Please give reasons for your verdict

- The protocol is clear and has no ethical issues. But for the benefit of the applicant, the literature review can be given a relook - to be organised around ideas, themes or theories not just listing or moving from one study to another.

DATE: 19/12/2022