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Implementation of STEM Education in the Zambian Education System: A Failed Project?

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ABSTRACT
The growth for the need of quality and relevant education is getting popular worldwide. The establishment of Science, Technology, Engineering and Mathematics(STEM) Education in Zambia is a response to this call and in line with the Zambia Educational Curriculum Framework of 2013 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. However, it appears the implementation of the programme has hit a snug and its implementation has been halted. Therefore, this study sought to establish the challenges in the implementation of STEM programme in selected secondary schools in Zambia. The study adopted a qualitative approach. A descriptive survey was used as a research design. Purposive sampling technique was used to sample teachers at STEM schools. The instrumentused to generate data was an interview guide. The key findings were that STEM education teacherswelcomed this progamme but had the following challenges: lack of teaching and learning materials, improper training on STEM curriculum, poor internet connectivity for research and poorly stocked laboratories. Based on the findings, this study recommends to the Ministry of General Education (MoGE) to be making wider consultations with key stakeholders before a programme is rolled out for implementation.

Keywords: *STEM, implementation, Policy, Curriculum.*

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INTRODUCTION

BACKGROUND AND CONTEXT

According to Ramli, Ibrahim, Bunyamin, Jamaluddin, Abdullah and Surif[1], STEM education is an interdisciplinary approach to education that applies concepts of Science, Technology, Engineering and Mathematics to overcome high-tech industry economic challenges. It is an approach to education that integrates the four disciplines, namely, Science, Technology, Engineering and Mathematics. Further, Hernandez, Bodin, Elliot, Baharuddin, Rambo-Hernanfez, Chen and de Miranda [2] contend that this integration is also known as a meta-discipline, the creation of a discipline on the integration of other disciplinary knowledge into a new 'whole.' This means that through STEM education, learners are given opportunities to engage into scientific investigations through hands-on activities and experiments. Consequently, STEM education provides the skills needed by learners in order to successfully meet the 21st Century challenges [1]. According to Diana, Turmudi and Yohannes[3], STEM education is an approach to learning which promotes the 4C skills: Communication, Collaboration, Creativity and Critical Thinking. This requires appropriate and intensive training of teachers to ensure that they know when and how to teach using specific methods. To this effect, teachers' readiness to implementing STEM education needs to be investigated.

The development of the STEM Education curriculum in Zambia started in December, 2019 when the Ministry of General Education was given cabinet approval to commence the implementation of the STEM curriculum in fifty-two (52) pilot secondary schools[4]. For this purpose, a transitional Curriculum was designed based on the Zambia Educational Curriculum Framework of 2013.The rationale of having STEM schools in the contemporary education system and industry is that it offers students one of the best opportunities to make sense of world holistically. Furthermore, STEM leads to innovation and innovation leads to new products and processes that sustain the economy. According to Ismail [5], STEM education is necessary to facilitate economic development, international competitiveness and job creation.

It should be noted that quality education is key to preparing the young generation with the knowledge and skills to address present and future socio-economic and environmental challenges, such as global climate change, digitalization and globalization[6]. This entails that learners should experience a school that reflects the reality of these challenges, and STEM schools should be such. In this sense, STEM education should be seen as an innovative approach to education and features extensively within the global landscape of educational policy and reforms. According to Ercan and Sale [7], this approach not only addresses the aims of policy reforms, such as ensuring competency in Mathematics and Science, but also emphasizes that it is no longer sufficient for modern citizens to understand science and mathematics; their

knowledge must be integrated with technology and engineering. To this effect, STEM education uses a learner-centered' approach to develop learner's self-direction, problem solving, collaboration and project management. It also drives innovation through creating, designing and producing solutions to real-world problems and uses real-world challenges as entry points for integration of STEM disciplines. Thus, replacing the traditional teaching methods.

Though STEM education has been in existence since the early 1990s in the United States, in Zambia, its implementation commenced in 2020.However, on the 7th of May, 2021, the Permanent Secretary Technical Services (Ministry of General Education), Dr. Jobbicks Kalumba, issued a circular to stop the implementation of STEM education after what was described as concerns from different stakeholders on the provision of STEM education. This paper is intended as a forward-looking and policy-oriented paper which will assist the Ministry of General Education, Policy makers and the other stakeholders to effectively implement high quality secondary school STEM education in Zambia.

METHODOLOGY

The study adopted a qualitative approach to generate data because the views and opinions of the teachers, pupils and administrators were sought.. A descriptive survey was used as a research design. Both homogeneous and heterogeneous purposive sampling techniques were used to sample teachers, pupils and school administrators. Ten (10) STEM schools were targeted, one from each of the Ten (10) provinces. The instruments used to generate data was an interview guide. Participants in this study were teachers of STEM education. Thirty (30) teachers, three (3) from each province were subjected to interviews. Data was analysed using inductive thematic analysis because the themes were strongly related to data.

THEORETICAL FRAMEWORK

This study was guided by the Triple Helix Theory of Innovation which was propounded by Etzkowitz, Henry and Leydesdorff, Loet in the 1990s. Etzkowitz and Leydesdorff[8] argue that the interactions between the academia (University), Industry and Government fostersa smooth and successful implementation of a programme. In terms of the driving force between government, industry and academia, Etzkowitz[9], argues that no particular element is necessarily the driving force of the triple Helix Theory of Innovation. Scholars such as Galvao, Mascarenhas, Marques, Ferreira, Ratten[10] view this theory as a lens through which evolving relationships between academia, industry and government can be analysed. However, according to Etzkowitz and Leydesdorff, it can also be a policy making tool, an aspect that makes this theory relevant to this study.

Contextualizing this theory into the current study, one would argue that before a programme is rolled out for implementation, there is need for stakeholder engagement. The role of the academia is to provide education to individuals and to do research which should inform policy. Further, the academia is supposed to provide research on which industry will build upon to produce goods and services. This could be done through conferences, formal and informal communication and article publications. On the other hand, government should provide funding to institutions that are still funded. This would ensure the academia has support in terms adequate teaching and learning material, infrastructure and funding for research. This means that there should be closer ties between academia and government. According to Chifuwe, Simui and Muleya[11], an investment in education brings out the capacity in the investor to work and adapt to new life because education instills in the individuals the correct approach towards life. The industry should come up with new ways of doing things to fit in the modern trends. In this sense, a collaborative approach between the academia, government and industry should be the way to go if implementation of policy is to be successful.

RESULTS AND DISCUSSION

This study focused primarily on establishing the challenges teachers faced in implementing STEM education in secondary schools in Zambia for the purpose of informing policy. To do so, the following were investigated;

a) Teachers` understanding of STEM education
b) The benefits of STEM education to the learners
c) Teachers` preparedness to implement STEM education
d) The challenges teachers faced in implementing STEM education

Teachers` Understanding of STEM Education

The results showed that all the participants seemed to know what STEM education was about. When the teachers were asked to give their understanding of STEM education, the following were some their responses.

STEM education is an approach to teaching were learners are drivers of their learning (T.1)
STEM education is 21st century approach which use constructivists approaches (T. 2)
STEM education is an approach that puts a pupil at the center of learning and the teacher is a facilitator (T.3)
STEM education is an approach to learning aimed at producing critical thinkers (T. 20).

From the responses given, it was clear that STEM education was an approach to learning aimed at producing learners who were creative, analytical, autonomous and critical thinkers. This is in line with Ramli, Ibrahim and Svof[1] who contend that STEM education focuses on active learning that involves a lot of hands–on activities by creating new solutions to complex problems. By implication, STEM education takes the inquiry based learning approach. By inquiry based learning approach, the learners are given an activity which makes them arrive at a given concept through engagement, explanation, exploration, elaboration and evaluation. Furthermore, learners are continually engaged in rigorous instruction, and this makes STEM classrooms different from the ordinary classrooms. By using constructivist approach to learning, learners build their own understanding of new ideas. The ideas learners usually bring are alternative to currently scientific acceptable ideas or alternative conceptions. According to Chien and Lajium[12], learners in STEM education are proficient in applying, creating, evaluating and critical thinking.

Critical thinking can be understood as a practice of processing information in the most skilful, accurate and rigorous manner possible for the benefit of an individual and society [6]. This means critical thinking skills in the learners will help them to make responsible decisions about their lives, behaviour and actions with full knowledge of the consequences and underlying assumptions of the choices made. One can also argue that STEM education has the potential to produce informed citizens who are capable of using critical thinking in making intelligent decisions about everyday challenges of life. In this vein, the teacher should ensure that the learning experiences incorporates problems which are important to the learners and not just to the education system. With this approach to education, learners are more likely to retain and transfer new knowledge to real life. Hence, STEM teachers should be seen using problem solving methods in their teaching. Problem-solving as a teaching strategy actively engages learners in practical learning activities. Furthermore, this approach to learning gives learners an opportunity to explore their environment in search for solutions to problems and challenges they encounter in society. When learners are given the opportunity to play a reading role in the teaching and learning process, they are without doubt engaged in the process of critical thinking. It is clear from the findings that the guiding principle of STEM education was centered on Outcome Based Education. A move from behavioral to constructivism pedagogy which equips learners with knowledge, skills and values.

The Benefits of STEM Education to Learners

This study showed that teacher were aware of the benefits of STEM education to the learners. This approach was viewed as significant because of the benefits it brings to the learners. When asked about the benefits of STEM education to the learners, the following were the responses;

STEM education helped to develop analytical and organizational skills in research (T.10)

STEM education help to apply theory into practice (T.8)

STEM education helped leaners acquire survival skills that will enable them produce actual products and become self-reliant, for instance, in wood work, the learners would be able to make desks (T. 3)

From the responses given by the participants, it was clear that STEM education informs classroom practice and makes learning more meaningful and ensures acquisition of quality knowledge and skills. This means that education works best when it concentrates on thinking and understanding rather than from rote learning. This finding was in line with the findings of scholars such as Magasu, Muleya and Mweemba[6]; Good and Brophy [13], who argued that teaching is about learners being engaged and not being spoon-fed. This observation is in line with the revised Zambia Education Curriculum Framework of 2013 where teachers have been encouraged to as much as possible use methods which help the learners think, reflect and do, rather than reproduce from rote learning [14]. Essentially, STEM education concentrates on thinking and understanding, rather than on rote memorization through the use of technology.

STEM curriculum allows the learners to participate and have the interface with the real life situation through deeper learning approaches which support learner engagement in the 21st century of critical thinking, problem solving, collaboration and self-directed learning [15].This means that STEM education seeks to link education to real life experiences as it gives learners skills to assess, criticize, analyse and practically apply knowledge to address societal challenges.

The development of learners' creativity has been a subject that the education sector always gives considerable thought on [16]. Learners need to be provided with relevant learning experiences and opportunities in order to learn to observe the world from a variety of angles and to analyse, categorise and really delve into the problems they encounter in learning as well as in lives. In addition to using a microscopic view to analyse the characteristics of learners' memory representations, educators should also adopt the macroscopic perspective to help build a creative learning environment and to advocate the importance of the development of higher-order cognition in students [17]. Not only do learners need to participate in activities in order to understand the diverse nature of knowledge, but they need a diverse range of activities to help stimulate their general and critical thinking abilities.

Therefore, the focus of STEM education is to produce a holistic learner who is creative, critical, analytical and innovative. The constructivist learning approaches used in STEM education make learners to be active participants. This learner driven approach to teaching and learning ensures that learners spend adequate time on various learning activities so that they develop the necessary skills and competences needed in life. The learner will be able to exhibit expected scientific skills if there is an effective reflux relationship between the teacher and teaching and the learner and learning process.

Teachers` Preparedness in Implementing STEM Education

The responses showed that teachers were ready but not adequately prepared by the Ministry of General Education to implement STEM education. The following were the responses;

Training was not enough. Teachers were not trained but oriented through Zoom meetings (T.1)

No, the teachers were not fully equipped with the knowledge about STEM education. Training was poorly done, considering that it was done via Zoom with poor internet connectivity (T. 6)

Teachers were not trained but oriented on the syllabus of STEM education (T.3)

There was no training but more less like illustrations to the teachers and there no any kind of assessments to determine whether they understood or not (T.2)

For teaching to be effective, a teacher has to be provided with appropriate and intensive training to ensure that they know when and how to teach using specific methods [18]. This means that a teacher who is a driver of success of teaching should be prepared before the implementation of a curriculum. According to Magasu, Mutale, Gondwe, Mubita and Kombe[19], a teacher plays an important the learners' acquisition of knowledge and development of skills needed in their future survival. This is because it is believed that competency-oriented teaching has become the most outstanding aspect of teachers' responsibilities in modern teaching.

Studies by Nambela[20]; Kombe[21]; Magasu, Muleya and Mweemba[6]; Magasu et al [19]; Konstantinos and Charl[22] have indicated that a teacher who lacks competencies will not deliver as expected. For instance, Konstantinos and Charl[22] state that the core of teacher's knowledge is firstly linked to the exhaustive mastery of his subject – matter adequate methods and means to convey it. Therefore, teachers have a great role play if pupils are to learn. This can only be achieved if the teacher has received proper training. Once the teacher knows how to handle the learners, learning becomes easy. The education system in Zambia like in any other country keeps on changing. Because of the nature of education, teachers are themselves supposed to be perpetual learners. According to Goessi[23], in- service training is an effective means of keeping teachers alert to constantly adapting their teaching to the changing social environment and in this case, the curriculum change. Therefore, the implementation of any given instruction depends on how knowledgeable the implementer is, hence the need for adequate preparation. It is believed that for any success in teaching to take place, the teacher needs to be more knowledgeable than his/her learners and hence the need to prepare them for any change that take place in the education system. Ali [24] postulates that the quality of an education system cannot exceed the quality of its teachers. Therefore, the implementation of STEM education demanded stakeholder engagement. Particularly, the government through the Ministry of General Education should have engaged the academia in research before rolling out this programme to determine whether teachers were prepared to implement STEM education.

Challenges in Implementing STEM Education

This study showed that the implementation of STEM education in secondary schools had a number of challenges. Schools were not adequately prepared to meet the demands that came with STEM education which perhaps, necessitated its abandonment. The following were some of the challenges from the teachers;

Poor internet connectivity, coupled with expenses to using internet facilities. This was the source of data. This proved to be very coasty for schools(T. 6)

Poor infrastructure. Laboratories were not equipped for experiments (T.8)

Lack of machinery, tools, equipment for some subjects to conduct practical's for instance, computers for computer science (T.3)

Practical's were not standardized but were dependent on how well the school was equipped (T.12)

*STEM syllabus had no time frame, learners were encouraged to explore (*T.8).

The curriculum was poorly phrased especially on the part of practical(T.3)

There was abrupt shift in teaching methodology, so teachers could not cope with the change (T.3)

Learners were allowed to come with computers, cell phones of which in most cases were misused by the learners. (T.13)

Preparation of lessons was a challenge. The content was open ended. The syllabus did not spell out how far the learners could go in terms of content. (T.9) *Conducting national exams would be a challenge.*

Based on responses from participants, it was clear that teachers had challenges in preparing their lessons. Teachers needed to be grounded and understand the structure of STEM curriculum to learn the unfamiliar content knowledge in order to help the learners to learn. Meaning STEM education requires well-thought of strategies, methods and resources

taking into account specific requirements and contexts of the groups of people to which the teaching and learning process is intended. Therefore, the three components, knowledge, skills and values were crucial.

Since STEM education is about hands-on activities, laboratories and, design and technology workshops were crucial, but left much to be desired. This dilapidated nature of laboratories and workshops contributed to teachers' reluctance to implementing STEM education. Schools needed infrastructure and tools but in most schools these were unavailable or in poor condition. According to Ramli et al [1], a conducive laboratory should be made to support STEM learning. The government needed to fund the academia adequately to support STEM education. This collaboration is crucial in sustaining STEM education in Zambia.

The government through the Ministry of General Education should take a deliberate move to orient teachers on STEM curriculum. According to Nambela[20] in Magasu et al [19], teachers' preparedness must be nurtured so that they would have a strong inclination towards the curriculum being implemented and strong tendency to embark on the implementation. However, the findings indicate that they were not prepared to implement STEM curriculum. Walinga[25] contends that in order for teachers to implement the curriculum successfully, they have to be ready for change to avoid resistance. This could explain why they found STEM curriculum challenging to follow. Furthermore, Mwanza[26] contends that teachers are end-users and when they are not aware of the objectives of a curriculum, it may not be possible to successfully implement a curriculum. Therefore, it is critical for teachers to understand the theoretical underpinnings of a curriculum in order to interpret it accurately.

With regards to teaching and learning resources, Bishop [27] argues that the ability to implement curriculum innovation is a function of the availability of the tools for the job. This view was in line with Miller and Seller [28] who argue that instructional materials are critical ingredients in learning and the intended programme cannot be implemented without them. The fact that schools had challenges with internet connectivity means it was difficult to implement STEM curriculum. This means that instructional materials provide information and opportunities for real learning. Without teaching and learning materials, the teacher may not teach effectively.

CONCLUSION

In conclusion, this study has made an attempt to bring out the challenges teachers faced in implementing STEM education for the so purpose of determining whether it was a failed project. The fact that the findings reviewed numerous challenges critical to the implementation of STEM education such as poor internet connectivity, lack or poor infrastructure and equipment, and poor training on the part of the teachers. This study therefore is in support of the Ministry of General Education's move to halt the implementation of STEM education in secondary schools in Zambia. It is indeed a failed project and it appears key stakeholders were not involved in the planning phase. The Triple Helix Theory of Innovation should have been considered before the implementation of STEM education.

RECOMMENDATIONS

Based on the findings, this study makes the following recommendations;

- Since STEM education is practical in nature, the government through the Ministry of General Education should equip STEM schools with appropriate teaching and learning materials such as laptops, internet facilities, tools, specimens and others
- Teachers should be well trained to understand STEM curriculum so that it is implemented accordingly
- Key stakeholders such as the Examinations Council of Zambia, Universities and Colleges of Education should be engaged at planning level

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