Possibilities for Implementation of STEM Education in Zimbabwean Under-Resourced Mathematics Classrooms

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Abstract

STEM (Science, Technology, Engineering, and Mathematics) is a current buzzword in school education in many countries. Thispaper reflects on the meaning of STEM education and considers how the kind of learning and instruction implied in this thrust could play out in under-resourced Zimbabwean mathematics classroom environments. This qualitative case study, explores the implementation of STEM education in the mathematics classrooms. Three (3) form three mathematics teachers teaching at two (2) community high schools were interviewed and observed teaching. Seventy (70) form three pupils completed an open-ended questionnaire. Narratives from the questionnaire and interview transcripts were analysed thematically. Results show that mathematics is not being taught as a practical subject. STEM has been introduced in schools but very little professional development on how to implement it has been done. STEM policies exist in schools but these policies seem not be fully adhered to, and may thus impact negatively on the quality of STEM programmes. Inquiry-based teaching strategies are not being utilised. Learners are not allowed to bring smart phones to school for learning purposes. After examining the main defining characteristics of STEM education, the paper proposes an instructional orientation that privileges inquiry and investigations and draws heavily from local everyday life phenomena, especially in less affluent community schooling environments. The phenomena may include indigenous knowledge resources and practices familiar to the learners while exploiting whatever limited but available ICT affordances.

Key words: *STEM education, indigenous knowledge and mathematics education, mathematics learning and ICTs*

Introduction

Ongoing calls to strengthen any nation's skills in Science, Technology, Engineering and Mathematics (STEM) are fuelled by the imperative to foster national and global economic growth (Marginson, Tytler, Freeman & Roberts, 2013). For this to happen, it is acknowledged that it is necessary to generate more graduates who have the capacity to pursue science-based careers (Office of the Chief Scientist [OCS], 2013). In fact, the essence of STEM is to prepare the 21st century workforce with STEM education and its related activities so that students can transfer what they learn in the classroom/laboratory and apply it to their future jobs in the real world. White (2014) argues that the utility of STEM gained momentum during the Second World War when scientists and mathematicians as well as engineers worked together with the military to produce products that assisted to win the war. STEM education is not only an issue that has aroused attention in educational circles in many countries but also the focus of their curriculum reform (Fan & Yu, 2016). A number of both developed and developing countries have fully realised that students' academic performances in science, technology, engineering and mathematics determines a country's economic development and competitiveness (Lai, 2018). The socio-economic future of Southern Africa lies in the region's ability to embrace STEM education as the main driver of economic development (Gadzirayi et al., 2016). Zimbabwe started to implement STEM curriculum in 2016. Parawira (2016) opines that the critical skills needed to drive economic growth within the context of Zimbabwe's economic blue print ZIMASSET, hinge on STEM education. Gadzirayi et al. (2016) also point out that a country's ability to innovate and compete in the global market is tied to the ability of the education system to prepare all learners in STEM.

Background to the Study

There has been a growing concern that STEM education is not preparing a sufficient number of students, teachers and professionals. In the United States, for the majority of students, knowledge of mathematics and science still fails to reach adequate levels of proficiency (Ejiwale, 2013). Ejiwale (2013) identifies poor preparation and shortage in the supply of qualified STEM teachers, lack of investment in teachers' professional development and lack of research collaboration across STEM fields as barriers to STEM education implementation. In Zimbabwe, Dekeza and Kufakunesu (2017) identify lack of laboratories; lack of STEM trained teachers as well as lack of scholarships for students pursuing STEM subjects as barriers to implementation of STEM curriculum. Gadzirayi et al. (2016) found out that the quality of STEM education in Zimbabwe is being compromised by unlearning environment, that is, dilapidated classrooms, poorly equipped laboratories and libraries as well as hot sitting. They also noted that a low level of access to grid electricity has implications for students and teachers' access to modern learning technologies that are computer based. In a case study of four single sex secondary schools in Bulawayo, Zimbabwe, Ncube and Sibanda (2018) found out that implementation of STEM education in the schools was constrained by lack of well-equipped science laboratories, lack of financial resources to purchase learning materials, especially chemicals, large class sizes, negative attitude by some learners, and limited parental involvement in their children's learning. The current paper explores the possibilities for implementation of STEM education in Zimbabwean under-resourced mathematics classrooms.

Defining STEM Education

STEM education refers to the technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science or mathematics education with the concepts of technology and engineering education (Sanders & Wells, 2006). From Tsupros (2009)'s perspective, STEM education is aninterdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering and mathematics in contexts that make connections between school, community, work and the global enterprise. Thus, STEM teaching goes beyond the mere acquisition and transfer of knowledge.

From the above definitions, STEM education intentionally situates the teaching/learning of STEM concepts to the real world experiences, providing hands-on and relevant learning experiences for students. Students are prepared to utilise mathematical skills to solve real-life problems using engineering and design principles. Thus, STEM education prioritises the study of mathematics and science, plus the meaningful integration of technology and engineering design that offers opportunities for innovative problem solving while making mathematics and science relevant and engaging, and developing the critical skills and career linkages students need to succeed in an economy which is deficient of skilled labourers and problem solvers. STEM education is therefore a methodology that encourages students to pursue inquiries and solve problems that are relevant to the world in which they live. Classroom experiences should mimic real-world scenarios and expose students to problem-solving in a significant way. The "new" 21^{st} – century jobs require a growth mind-set, the ability to solve problems, think critically, be innovative, multitask and work collaboratively with a diverse group of colleagues –colleagues who may be of different cultural or racial background.

Morrison (2006) suggests that STEM education should produce students who are:

- **Problem solvers** – able to define questions and problems, design investigations to gather data, collect and organise data, draw conclusions, and then apply understanding to new and novel situations.
- **Innovators –** creatively use science, mathematics, and technology concepts and principles by applying them to the engineering design process.
- **Inventors –** recognise the needs of the world and creatively design, test, redesign, and implement solutions (engineering process).
- **Self-reliant** – able to use initiative and self-motivation to set agendas, develop and gain self-confidence.
- **Logical thinkers** –able to apply rational and logical thought processes of science, mathematics, and engineering design to innovation and invention.
- **Technologically literate –** understand and explain the nature of technology, develop skills needed, and apply technology appropriately (Cited in Hays Blaine Lantz Jr., Ed., 2009 p. 3 (http:www.currtechintergration.compdf/STEMEduc).

This then present challenges for mathematics educators who are expected to contribute to the foundations of a STEM literate community. Some of these challenges were explored in this study.

Study Focus

Driven by the ongoing national and global calls to equip students with scientific, technological, engineering and mathematical skills needed to drive economic development, the study sought to explore how STEM education is being implemented in under-resourced mathematics classrooms in Zimbabwe and provide possibilities for implementing STEM education in such classrooms. Considering that learners in Zimbabwe are from diverse backgrounds, multiculturalism was used as a lens to view the status of STEM education in under-resourced mathematics classrooms. Being a multicultural society, Zimbabwe should embrace multiculturalism when implementing STEM education in order not to disadvantage certain social groups. According to Banks (1996) multicultural education is an approach that critiques and addresses current shortcomings and discriminatory practices in education. Marginson et al. (2013) highlight that STEM education should take into account the diversity of students' contexts such as gender, ethnicity, and race. Society's economic status was also considered in the study.

The study was guided by the following research questions:

- How is STEM education being implemented in Zimbabwe's under-resourced mathematics classrooms?
- What are the possibilities for implementation of STEM education in Zimbabwe's under-resourced mathematics classrooms?

Methodology

The study was qualitative in nature. A case study design which permitted use of data from a self-developed open-ended questionnaire, three interview transcripts and six lesson observations was employed. The sites were two secondary schools, one at a rural growth point and the other in a typical rural setup. Both schools are in Chivi District in Masvingo Province, Zimbabwe. These were rated as poorly-resourced schools since they had no infrastructure that supports sciences and specialised resources such as computers. Also the schools had overcrowded classes. This was established during Teaching Practice supervision visits. The sample participants were seventy (70) Form three mathematics learners from the two purposively selected schools and their three mathematics teachers, two from the growth point school and one from the other rural school. The multiple data sources (Merriam, 1998; Yin, 2003) served as corroborating evidence to enrich the picture of the teaching practices presented in the study.

Quotations from learners' questionnaire responses and interview transcripts were used as narrative stories told by learners evaluating their participation in STEM education. The narrative stories were thematically analysed. The interviewed teachers were referred to as TR A, TR B and TR C in the study. Purposive sampling was used to select the research sites. Merriam (2009) identifies purposive sampling as one appropriate sampling strategy in case study design. Merriam (ibid), further adds that purposeful sampling is based on the assumption that one wants to discover, understand, gain sight; therefore needs to select a site from which one can learn the most.

Research Findings and Discussion

The following are the main findings which emerged from the collected data:

1. Institutional physical support draws back well implementation of STEM education.

2. Inquiry-based strategies are not being used in mathematics classrooms.

3. Mathematics teachers need professional development to equip them with deep content knowledge in STEM and strong pedagogical skills for successful implementation of STEM education.

4. Learners are being discouraged from using cell phones as learning resources in mathematics classrooms.

Lack of institutional physical support

The study established that both schools used in the study had no mathematics laboratories or simply mathematics rooms specialised for the teaching of mathematics. When interviewed, all the three mathematics teachers indicated that their teaching environments were not conducive to mathematics teaching and learning as per STEM demands which are outlined under the definition of STEM education. When asked whether he sometimes involve his learners in practical work during mathematics lessons, TR A indicated that, "*Teaching mathematics as a practical subject is not very effective here because our classes are rather too crowded".* This according to TR A, indicates that classroom overcrowding can make facilitation of students' activities less-effective. Since the classroom is the most important area within the school where students spent most of their time, reduction of class size can result in higher achievement for children living in poverty (Ejiwale, 2013). The classroom environment should be made conducive to learning (Hibpshman, 2007 &Deines 2011). TR B had this to say, *"Our school is poorly-resourced that thinking of having a laboratory or a special room for mathematics teaching is being too ambitious. The requirement is rather far-fetched in an environment which does not even have text books."* On the other hand, TR C emphasised the need for mathematics special rooms or laboratories as follows: *"From the look of it, these STEM subjects cannot be taught in ordinary classrooms, we really need laboratories".* Inadequate facilities will continue to weaken STEM education implementation at all learning levels, primary, secondary schools and tertiary institutions (Ejiwale, 2013). Unfortunately, most schools' facilities used for learning today were constructed before World War II and 40% were not built for STEM education but for industrial arts (the National School Boards Association, 1996). This is the situation in Zimbabwean schools. Ejiwale (2013) laments use of archaic facilities in schools which do not match the demands of STEM.

When asked to comment on the necessity of mathematics laboratories, all the interviewed teachers had a positive mind on how the availability of laboratories might help their pupils in the understanding of Mathematics. "*The School authorities must adopt to scientific ways of delivering Mathematics to 'O' level pupils making it an innovative subject so as to meet the requirements of STEM, therefore, Labs must be built so as to make Mathematics a more practical and scientific subject",* TR C explained. One student reiterated during focus group interviews, "*A practical lesson in mathematics! That's impossible here."* Ninety two (92%) percent of the students indicated that they had never done a single practical lesson in mathematics. Since there are some topics like "locus" which are always done practically the student may be of the narrow opinion that practical lessons are always done in laboratories. These students had the same sentiments as their teachers on the necessity of a mathematics laboratory. On the suggestions to promote the teaching and learning of mathematics under STEM education, one student, wrote, *"We as Mathematics students we should be taught Mathematics in a way that is scientific to understand its roles and application in the scientific world".* This shows that students lack confidence in the way mathematics is being taught. This lack of confidence may have a detrimental effect on their performance. The Malaysia Education Blue print (2013-2025) indicates that one of the factors that compromise student outcomes in STEM subjects is limited infrastructure. According to Gadzirayi et al. (2016) schools should have well equipped classrooms and laboratories for the effectiveness of quality education and success of STEM education.

Inquiry-based teaching and learning

Inquiry-based teaching and learning strategies are not being used in the mathematics classrooms as expected. Capps and Crawford (2013a) point out lack of understanding and knowledge of inquiry as a reason for teachers not using inquiry-based teaching and learning strategies. Learners are not given enough chance to construct and ask questions during lessons. From the six lessons observed (two from each teacher) seventy four percent (74%) of the questions came from the teachers and most of the questions were not all that challenging to stimulate students to problem inquiry. Bybee (2010) suggest that challenging tasks or questions can be utilised to stimulate students to use STEM to find solutions. Silm et al. (2017) also argue that inquiry-based learning is a student-centred way of learning where students develop their own questions to examine and engage in self-directed inquiry. Instruction should be organised around authentic students' questions where concepts and skills are developed within real-world contexts. But as indicated above, most questions came from the teachers. During group work activities, learners were simply following teachers' instructions, thus following a step by step nature of teaching. In those groups not all members brought their best strengths and skills to the table to share. Those students who acted as group leaders were the most, if not the only, active members in group activities and feedback presentations. From those observations one can conclude that working as a team is different from working in groups, the ability to work in a team is an important skill which needs to be learned. Teachers should not underestimate the importance of spending time teaching their pupils how to learn, how to take ownership of their learning, and also how to work as a team.

However, when the three interviewed teachers were asked whether they were using inquiry-based teaching in their mathematics classroom, they all indicated that, pupils were allowed to ask questions and bring new ideas as they learn. This was not much in agreement with what transpired in the observed lessons. In support of the inquiry-based strategies, TR C reiterated, "*Through inquiry-based teaching strategies, teachers' will determine where their pupils are lacking and at the same time know where they are strong in the learning of mathematics"*. Thus, inquiry-based teaching strategies are powerful tools for educators looking to connect with their students and apply STEM principles. But some students feel the method can act as an intimidating weapon used by teachers to scare them off. "*Each time my teacher says I should ask a question, I feel like I am being intimidated and that I don't understand much on what is being taught",* one pupil explained how inquiry-based teaching was affecting her. Learning how to do inquiry-based learning is an important part of the process. Teachers should not expect children to intuitively know how to be self-motivated learners who can embrace the freedom of these approaches. Teachers need to make their learners comfortable first. Sometimes just becoming comfortable with new processes or learning techniques is the most important lesson of the day. Self confidence in one's ability to learn is the key to empowering a student to become a lifelong learner.

Professional development on STEM education

The successful implementation of curriculum reform hinges on the quality of the implementers, the teachers. In respect of STEM curriculum, the STEM educator should assume the new role, a facilitator in the classroom or laboratory. As such it is necessary to address and reduce the barriers to successful implementation of STEM education. Ejiwale (2013:64) identifies some of the following barriers to STEM education that are attributable to the loss of interest in STEM disciplines by students who would have become future scientists, engineers, and technologists, thus : “Poor preparation and shortage in supply of qualified STEM teachers, lack of investment in teachers’ professional development, and lack of collaboration across STEM fields”.

In the study, when pupils were asked to indicate their reasons for misunderstanding mathematical concepts, 70% of the pupils blamed their teachers. Many of them argued that teachers poorly explain their points, “*Teachers fail to elaborate and they give learners incomplete information resulting in us yielding poor results”,* wrote one student. Another student wrote, “*Lack of patience, skills and explanations from the teacher lead to poor results in STEM fields”*. This shows that some students expect teachers to spoon-feed them instead of teachers playing a facilitatory role. Therefore, teachers need strong professional development to be able to play their new facilitating role in STEM education. Posamentier and Maeroff (2011) note that who teaches in STEM programmes matters. To support this argument by Posamentier and Maeroff (2011), Watkins and Mazur (2013) assert that a typical elementary school teacher that has minimal preparation in any STEM field tends to lack confidence in his/her knowledge of the subject and may bequeath this anxiety to students. Teacher’s preparedness will contribute positively to successful implementation of STEM education.

For successful implementation of any curriculum reform, teachers need professional internships for clinical training. When asked on whether they had attended any workshops on STEM, TR B said, “*In our district only two workshops on STEM were held and it was like a crash programme on the expectations of the teacher’s role when teaching STEM disciplines. We did not benefit much”.* Referring to lack of professional development, TR C also pointed that, “*There is little in-housetraining for teachers so as to produce quality results as far as STEM education is concerned”.* TR A from the school in a typical rural setup had this to say, *“We read about STEM education in print and electronic media, but have never attended workshops on how to implement the type of education. We are not comfortable in implementing this curriculum reform. We also do not have textbooks on the expected pedagogy”.* The lack of investment in the professional development of teachers for a strong knowledge base has been attributed to poor student performance (Ejiwale, 2013). Inspired teaching inspires students. Therefore there is need for more workshops on STEM education implementation since the research showed that little was gained from the district hosted workshops. For quality teaching there is need for quality professional development as well. The Australian National STEM School Education Strategy (2015) emphasises that quality teaching is a key factor to lift student engagement and performance in STEM education. In this regard Mervis (2011), asserts that "anything that dilutes ingredients such as, poor teacher preparation and professional development and a disregard for low-achieving students, will lower the chances of success". Teacher factor is thus a crucial cog in the successful implementation of STEM education.

Use of cell phones by students

From the observed lessons there was no technology at all to enhance effective conceptualisation of content. When asked whether their schools were providing enough equipment for the learning of mathematics electronically and technologically, 95% of the pupils indicated that their schools were not providing devices in the form of computers, smartphones, and internet facilities for their learning of mathematics. Some pupils had such views on how electronic devices could be helpful in their understanding of mathematics, *"They should allow us to use our cell phones for research purposes and share ideas through social media"*. In addition to the above, most pupils opined that the education sector should improve on the issues of technology in the teaching and learning of mathematics. The pupils explained that the authorities at their schools were regarding ICT devices (especially cell phones) as destructive rather than educative. *"Since the introduction of the Ruzivo electronic learning through smart phones and computers "O" level pupils have been willing to learn mathematics technologically. However, it has been a set back with school authorities not providing proper equipment and at the same time not allowing "O" level pupils to bring their devices(especially cell phones) to school for learning purposes", argued TR B.* Hence the provision of technological ways of teaching and learning of mathematics has been a major setback at the two studied schools. When asked why they were not being innovative in providing some technological replacement of computers when teaching mathematics, all the three teachers indicated they were still illiterate in the innovative ways. Although at the growth point school the Headmaster indicated that there were few computers which could be used for teaching, teachers had no basic knowhow on delivering mathematics lessons technologically. This again takes us back to the need to professionally develop the teachers.

From the study, the researcher observed that teaching and learning of mathematics had a more basic approach than the way the STEM education approach has in its nature. Technological methods have not been put in place in the way STEM education has been adopted and implemented. School authorities still think that technology can cause pupils to go astray rather than learning. To ensure that STEM education is adopted and implemented thoroughly and successfully, schools should introduce teaching and learning of mathematics using devices and internet. Carr (2012) argues that the use of iPads at times appeared to initiate higher order thinking and conceptual knowledge for students learning mathematics, by enhancing the students' engagement, practice and reinforcement of concepts. Carr (2012) also considers teacher professional development and technical support as key elements of utilisation of the mobile technology.

Bringing STEM education into under-resourced mathematics classrooms

Skills do not just automatically form in people. They must be learnt and formal education is the logical conduit for that learning. In STEM education what is needed is a commitment to find new and innovative teaching methods to engage students in science, technology, engineering and mathematics. A greater focus should be placed on those activities that allow students to engage in real world problems and experiences through experiential learning activities that lead to higher level thinking. Even if teachers do not have access to expensive resources, every classroom can become a maker space where students and teachers learn together through direct experience with an assortment of local materials to be collected from the students' environment.

In line with STEM education's intent, game-based learning provides authentic learning experiences. Taking "*tsoroyemakomba"* as an example, the game may be used to teach probability in mathematics classrooms. This game is usually played on wooden boards, which have four rows of eight holes each (4x8 board), carved into them. It is played with a predetermined number of identical counters (usually seeds) placed in the holes. The playing of this game involves simple and complex moves in the process of spreading seeds in the holes. The goal is to immobilize or annihilate the other player(s) by the capture of the majority of seeds. The topic 'probability' has thus been indigenised to match the activity of playing "*tsoroyemakomba"*. Through mathematisation, some questions on probability may be constructed and used as classroom activities. When learning in this authentic learning environment, the player sees the relevance in learning the content for the purposes of playing the game. The analysis of how *tsoro* is played which was done by Masiiwa (2001) brings out some high-powered mathematical concepts. Using the exponential number 2^n, Masiiwa discovered that *chihwangu*– thus winning in one turn occurs for:

2^n holes per row and 2^n -1 pebbles in each hole.

Masiiwa (2001) also claims that playing of *nhodo* involves counting and the concept of factors. There are many educational games which can be availed in the classrooms. There are also non-educational games that can be paired with instruction to make the game educational. All what is required is the innovativeness of the teacher. Taking for example the *tsoro* game described above, where the *tsoro* boards are not available, they can be improvised through carving out small holes on the ground. Game-based learning is fast becoming a trend in education. Teachers are experimenting with not only using games but also game mechanics in the classroom. Games may be used in the classroom to not only leverage engagement but also to align games to instructional principles. Games are excellent models for assessing best practices. When playing games, students are given the freedom to fail and are given specific feedback through formative assessment on how to improve. When players win the game (summative assessment) they are awarded with a true sense of accomplishment as the assessment is meaningful.

Where modern technology is not available teachers should make use of the funds of knowledge in their environments, thus, bringing in the indigenous knowledge systems in the school system. Indigenous artefacts may be analysed to extract the embedded mathematical concepts and processes involved in coming up with such artifacts. This aligns with the concept of engineering so critical in STEM education. Use of local knowledge is quite suitable in STEM education since, as advocated by Kelley and Knowles (2016), most content in STEM can be grounded with the situated cognition theory (Lave & Wenger, 1991). Foundational to this theory is the concept that understanding how knowledge can be applied is as important as learning the knowledge and skill itself. Local people from the community who have special skills related to mathematics application may be invited to come and demonstrate their skills in the mathematics classrooms. When a student develops a knowledge and skill base around an activity the context of that activity is essential to the learning process (Putman &Borko, 2000). Often when learning is grounded within a situated context, learning is authentic and relevant, therefore representative of an experience found in actual STEM practices. For example basket and mat weavers may demonstrate the processes involved in coming up with baskets and mats. Some of the processes are depicted in the following pictures:

The above figure demonstrates the idea of perpendicular lines.

To make sure the sticks representing the walls of the basket are upright, the top and bottom holes to fit the vertical bamboo sticks are bored maintaining constant corresponding distances apart.

The above diagram illustrates the starting point when making mats. A pole is graduated into equally spaced grooves that are smoothened. The hanging stones illustrate the motion of connected particles. The grooves act as pulleys. The smooth pulley allows the tension in the weaving string to be constant throughout the hanging length. Since the string is inelastic it does not alter its length under tension, therefore the acceleration of the particles attached to it will have the same magnitude. The force in each string is equivalent to **T – mg** where **T** is the tension in the string, **m** is the mass of the stone and **g** represents the pull of gravity.

The observation and analysis of the weavers' demonstrations will help to develop in students a more accurate vision of mathematics as a human enterprise, consider mathematics as a fundamental component of our cultural heritage, and appreciate the crucial sustainable role mathematics plays in our societies, thus, giving currency to the adage: *"Give a man a fish and he eats for the day.Teach a man to fish and he eats forever"*

This gives students a double advantage; one of learning the involved mathematical concepts and the other of learning how to weave. This is relevant when we consider Zimbabwe Agenda for Sustainable Socio-Economic Transformation (ZimAsset)'s aspirations of equipping students with psychomotor skills which can be useful in life after school. This leads to a fundamental re-orientation of the teaching and learning process to a more progressive approach to mathematics. Students learn with greater depth of understanding when they are actively involved in the process of discovering concepts. If we want students to develop a living relationship to mathematics, they must not experience mathematics as an artificial world that has nothing to do with their personal lives.

In under resourced schools without libraries, students can still be involved in research-based approaches such as problem-based learning. This could be by way of investigating IKS (through project-based learning) in the local environment and harnessing the embedded mathematical concepts. For example, students may be asked to compile a list of geometric figures used to decorate mats, baskets, fabrics, etc., in their cultures and also describe the involved transformations used in coming up with such geometric figures. This will help students in understanding cultural activities deeper as well as the involved mathematical concepts, thus, empowering learners mathematically, socially and epistemologically (Madusise&Mwakapenda, 2014).

M-Learning, using multipurpose mobile phones can be used as an alternative to E-learning. This is a user friendly teaching strategy to students who can afford the cell phones. The phones can even access the learning when off-line. Also through WhatsApp groups teachers can successfully communicate with their students on academic issues. This means teachers can meaningfully communicate with their students over the phone for teaching purposes. The success of STEM education in under resourced schools is also sustained by the teacher's innovativeness in indigenising the curriculum.

Also inquiry-based teaching is a strategy which can be used even in under-resourced mathematics classrooms. The inquiry-based mathematics education offers a robust learning ecology for enhancing mathematics instruction which is in line with the intent of STEM education. Artigue and Baptist (2013) present the following argument on mathematical inquiry:

> Mathematical inquiry starts from a question or a problem, and answers are sought through observation and exploration, mental, material or virtual experiments are conducted, connections are made to questions offering interesting similarities with the one in hand and already answered, known mathematical techniques are brought into play when necessary. This inquiry process is led by, or leads to, hypothetical answers – often called conjectures – that are subject to validation. [Artigue& Baptist, 2013, p. 4: http://www.foundation-lamap.org/sites/default/files/u]

Inquiry is at the heart of STEM's interdisciplinary approach, as students seek answers to questions raised by the curriculum and themselves. Within this interdisciplinary framework, students are still expected to meet content-area standards (Stevens, 2012) and this approach also nurtures a student's cognitive growth and involves a greater degree of collaboration than other instruction models. Mathematical inquiry is often motivated by questions arising from the natural world or the human made world around us. Since one of the main ambitions of mathematics as a human activity is to contribute to understanding of the natural, social and cultural world, and to empower human beings to act on this world, it should be noted that mathematics as a science creates its own objects and reality, and the questions raised by these objects have always been an essential motor of its development. For instance, numbers and geometrical forms have been used for centuries and are still incredible contexts for mathematics experiments. Also patterns, whether suggested by the natural world, resulting from human activities or fully imagined by the mathematician's mind, play a great role in nurturing investigative practices in mathematics.

From the above observations, teachers are expected to turn their classrooms into centres of innovative thinking and experimenting. Students should be given opportunities to practise formulating their own questions and finding answers to them. Transforming their questions into questions accessible to mathematical work is an important process of inquiry, engaging a modelling process. In modelling approaches, connections between mathematics and the external world become the focus of attention. In small groups, students may identify a problem, decide on how to collect data, collect it, and then interpret these data. In doing this, students count, measure and compute. What then is important is that mathematical operations are performed for a purpose: to answer questions that are important to the students about the problem under investigation, and generally about the real world. Inquiry-based learning therefore places students in a role of researchers where the quality of students' investigations is linked to the quality of their inquiry. Students start learning by exploring texts, materials, situations and events. The motivation for pursuing answers to their own questions is very strong. Teachers should value their students' questions, take joint action with their students on the basis of students' questions and production (Sensevy, 2011), create the conditions for students to make connections within mathematics and with the external world, and promote the cultivation of inquiry habits.

STEM education calls for improved teaching strategies in the classroom and opportunities outside the classroom to demonstrate linkages between mathematics and real-world applications. Such teaching strategies should enable students to see the synergy. Students must be able to tie their own think-nets. The more connections students establish between elements of knowledge, the denser and tighter the nets are woven. Therefore STEM pedagogy purposefully seeks to engage students in using/applying mathematics, science and engineering concepts and practices in designing, making and evaluating solutions to authentic problems. Mathematics teaching should not only focus on acquiring particular mathematics skills and results, but also focus on the necessary learning processes and strategies (thus bringing in the idea of engineering). Students should learn to structure, process, and present their own ideas. There should be less focus on isolated problems but more focus on problems within contexts. Such contexts should also include contexts which depict indigenous knowledge systems (situated contexts). According to Lai (2018) the purpose of STEM education lies in helping students improve their learning motivation for STEM disciplines and enhance STEM literacy, and in understanding how STEM knowledge can be utilised to solve real life problems.

Conclusion

The study explored the challenges being faced when implementing STEM education in under-resourced mathematics classrooms. It is argued that even in less affluent community schooling environments, STEM education can be successfully implemented. To be successful in implementing the STEM education intent, teachers are expected to be innovative in constructing learning environments where students learn through experience, talking and engaging in discourse. An instructional orientation that privileges inquiry-based learning and draws heavily from local everyday phenomena is proposed. The phenomena may include indigenous knowledge resources and practices familiar to the learners while exploiting whatever limited but available ICT affordances. School authorities should then not bar students from using cell phones for learning purposes. Putting this all together can offer promising pathways to achieving STEM education.

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