Science Teachers’ Conceptions of STEM Teaching and Learning in Masotsha High School in the Khami District in Bulawayo Province.

BY

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A project submitted to the department of Educational Foundations, Faculty of Science Education, Bindura University of Science Education, Bindura, Zimbabwe, in partial fulfillment of the requirements of the Master of Science Education Degree in Chemistry.

APRIL 2018
APPROVAL FORM

I, Dr. Vongai Mpofu, undersigned certify that I have read this project entitled: Science teachers’ conceptions of STEM teaching and learning at Masotsha High School in the Khami District in Bulawayo Province, conducted by Shaibu Adini Phiri; Registration No: B1544974 in partial fulfillment of the Master of Science Education Degree in Chemistry. I further approve its submission and recommend to Bindura University of Science Education for it to be examined.

Dr. Vongai Mpofu

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DECLARATION

I Shaibu Adini Phiri Registration Number B1544974 do hereby declare that this project has been as a result of my own unaided work and investigations and such work has not been presented elsewhere for the purposes of project assessment. Additional sources of information have been acknowledged by way of referencing. It is being submitted for the Master of Science Education Degree in the Department of Educational Foundations, Faculty of Science Education of the Bindura University of Science Education.

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-- day of --------------------------------- 2018
ABSTRACT

The issue of economic and industrial decline by the country has necessitated the government of Zimbabwe to introduce a new STEM curriculum to make science education relevant to the needs of the communities it serves. In this study, qualitative methods were used to explore from science teachers’ conceptions of STEM teaching and learning at Masotsha High School. The study specifically focused on the understanding of STEM, STEM-STEM education and new curriculum interpretation from the science teachers’ perspective. The study adopted case study strategy and generated data through semi-structured interviews with eight science teachers, teacher generated and analysis of new curriculum syllabi (document). The thematic analysis of data revealed that the science teachers have a poor understanding of STEM, STEM-STEM education and were still interpreting the new curriculum using the traditional and separatist ideology. Thus, it is drawn from these findings that many science teachers were not properly oriented in the implementation of the new curriculum and lack the pedagogical content knowledge and resources to tackle it properly. In some cases, teachers were showing resistance to the changes due to non-involvement in the crafting process of the new STEM curriculum and its inability to clearly define its content. The study recommended that science teachers need to be properly oriented in the new STEM curriculum and courses offered in order to upgrade them in the use of ICT tools and their pedagogical content knowledge.
DEDICATION

To my sons Mthandazo and Nkosinhle, my lovely wife Nobubele and brother, James; I appreciate the love and support you always give to me.
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LIST OF ACRONYMS

A-Level………………………………Advanced Level
CEIT………………………………..Commission of Inquiry into Education and Training
ICT………………………………..Information Communication Tools
IKS………………………………..Indigenous Knowledge Systems
MHTESTD…………………………..Ministry of Higher and Tertiary Education, Science and Technology Development
MoPSE…………………………..Ministry of Primary and Secondary Education
NRC…………………………..National Research Council
NSTA…………………………..National Science Teachers Association
O-Level…………………………..Ordinary Level
SADC…………………………..Southern African Development Community
STEM…………………………..Science Technology Engineering and Technology
STI…………………………..Science, Technology and Innovation
ZIMASSET………………………..Zimbabwe Agenda for Socio-Economic Transformation
ZIMSEC…………………………Zimbabwe Schools Examinations Council
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CHAPTER ONE: INTRODUCING THE STUDY

1.0 INTRODUCTION

The world is full of products and services of scientific research that have improved human life over several centuries. Economic development and growth of any nation has more and more demanded advanced knowledge and skills in science and technology. This has driven Zimbabwe, like any other nation, to introduce Science, Technology, Engineering and Mathematics (STEM) education curriculum reforms. However, its implementation requires that teachers, as agents of curriculum change, understand the demands of this curriculum. Yet these teachers have been subject specific teaching trained. At the same time research on what STEM teaching and learning entails particularly in the Zimbabwean context is void. The need to capacitate science teachers to implement the STEM curriculum from a research stand point becomes prudent. This research is undertaken for this cause. It begins with this introductory chapter. The chapter discusses the main research introduction aspects which include: the background of the study; the problem under study encompassing the statement of the problem, research questions and objectives; the significance of the study, assumptions of the study, delimitations of the study that incorporates the geographical setting of the study, the conceptual parameters and methodology adopted, limitations of the study and the definition of key terms. The chapter ends with the organisational framework of the study and a summary of issues highlighted in the chapter.

1.1 BACKGROUND TO THE STUDY

The transition to Information Age, that is, the Digital Age from Industrial Age, need human force skilled for technology and science related jobs (Dugger, 2010). Thus, learners at primary and high school levels up to higher learning levels at colleges and universities in the Digital Age must be conversant in STEM disciplines, that is, they need to engage in STEM integrated learning to capacitate them to solve complex real-world problems. The term STEM was pioneered and coined by Ramaley in 2001 in reference to science, technology, engineering, and mathematics (TIESTEM, 2010). It is worth noting that Science, Technology, Engineering and Mathematics are scientific fields of practice that either develop content knowledge or apply
the knowledge developed or both. STEM education is pedagogical discipline that focuses on the issue of knowledge acquisition and transfer. It draws from the knowledge produced by different scientific communities of practice and it is an interdisciplinary approach to teaching and learning (Tsipros, 2009). This relates integrated teaching of concepts drawn from different science related subjects where and matching to real-world lessons.

Despite an increase in the demand for having a workforce of scientists, technologist, and engineers, a decrease in learners pursuing STEM learning areas has been observed throughout the world (Cavas, 2012). In an effort to address this problem, many nations have taken initiatives such as an increase in scholarships for STEM disciplines. The Government of Zimbabwe has since joined this STEM initiative as announced, in 2013. Initially this nation developed a ZimAsset document. This is a five-year (October 2013 to December 2018) economic development blueprint. In short, ZimAsset visions, “Towards an Empowered Society and a Growing Economy.” The articulation by Mugabe (2013) that, “[ZimAsset] was crafted to achieve sustainable development and social equity anchored on indigenization, empowerment and employment creation, which will be largely propelled by the judicious exploitation of the country’s abundant human and material resources” succinctly defines its endeavours. The STEM curriculum reform was initiated to contribute to the goals of the ZimAsset through education across all levels. Yet educational research studies that inform on what STEM, and STEM education and later alone how teachers conceive these programmes are scarce in the literature. This research was undertaken to unveil the conceptions of science teachers of STEM, STEM teaching and learning and how this may inform successful implementation of this reform. Such research is important not only to inform likelihood of the successful implementation of the STEM education curriculum reform but also serves as knowledge and skills analysis survey.

The crafting of the STEM curriculum reform in Zimbabwe was also informed by the CEIT report recommendations. The major recommendation forwarded by CEIT to the government of Zimbabwe was that the Education system needed to shift from being academically oriented to approaches that produced products to fit in prevailing socio-economic in the country and beyond at large. This included a provision for an innovative ‘Four-Pathway’ approach to the development of vocational and technical skills among learners. In science Education, Zimbabwe like any other nation, who sees the teaching and learning of sciences as laying the
foundation for Science, Technology and Economic Development and Growth, saw STEM education as the most plausible path to follow.

The STEM curriculum mostly aims at producing and developing an all-round learner product equipped with basic skills encompassing manipulative, computer, and mathematical, civic, scientific, social, and linguistic skills individual at primary level (Mberi, 2016). Academics within the Ministry of Higher and Tertiary Education are decidedly convinced that STEM provides the optimum environment for the development of invaluable competencies such as problem solving, critical thinking, creativity, team work, communication skills and conflict resolution (MHTESTD, 2016). These skills are critically important for the socio-economic transformation of the country and should be encouraged and developed among students. Hence:

The ultimate objective of the STEM revolution would be to position Zimbabwe as a global leader in scientific discoveries and technological breakthroughs and effective exploitation of economic prospects from commercialisation of research results enhancing her competitiveness (MHTESTD, 2016).

The STEM curriculum will produce an individual who is able to adapt to any situation and able to develop solutions to the circumstances facing the individual. Adaptation and problem solving abilities are the key in developing innovative ideas to new arising problems.

STEM and STEM education, therefore, is the nerve centre of ZimAsset. It [ZimAsset] in Zimbabwe is poised to chart an industrial and economic transformation which Zimbabwe so desires to recuperate her ailing economy. This is because, as already alluded to in the previous sections, ZimAsset aims at transforming the Zimbabwean ailing economy. Hence attaining this goal is basically hinged in strong STEM Education and STEM programmes. STEM education is generally aimed at future development of the Zimbabwean economy and its commercialisation and industrialization endeavour. By 2021 institutions of higher learning will produce the first graduates from the STEM initiative and from 2021 to 2025 and beyond, the Zimbabwean society must look forward to transformational change in the application of science and technology in industry and commerce (Gandawa, 2016). It is envisaged that every aspect of the Zimbabwean economy by then will be viewed through the scientific lens, therefore, driving industry and commerce development.
Teachers as classroom practitioners are the main agents of curriculum change. The STEM curricula is new in Zimbabwe. It is introduced against teacher training background of subject specific teaching and learning. That is a teacher, teaching mathematics in Zimbabwean high schools has been capacitiated with the Mathematics content and its pedagogical knowledge. It becomes almost obvious that such teachers’ Pedagogical Content Knowledge (PCK) acquired through training and experience is limited to STEM teaching and learning. These teachers may therefore encounter challenges in understanding what STEM and STEM education entails and later on interpreting the STEM curriculum. It can be argued that trained teachers are expected to be able to tackle new content demand and shift their pedagogy to suit its teaching. However, without accompanying guidelines and teaching and learning resources the task of implementing the STEM curriculum becomes overwhelming to these teachers. Moreover, this STEM education reform is subsequent to many either failed or aborted science curriculum reforms in Zimbabwe. Teachers and laboratory technicians, where available, were rarely trained properly in the maintenance of the equipment, either in pre-service or in-service training programs (Lowe, 1985). For example, the Zimbabwe Secondary School Science Project (Zim-Sci project) meant to address shortage of teaching and learning was later on abandoned due to the fact that the Zim-Sci team was understaffed overloading the officers with administrative and bureaucratic duties and had little time for curriculum development (Musar, 1993). Musar (1993) further states that the rapid growth of the number of schools and a large turnover, many teachers were under-qualified, which resulted in underutilisation and less effective use of the kits. Later on the integrated teaching and learning of indigenous knowledge and western science in science lessons was introduced but also failed to take off. (Musar, 1993).

There are many reasons cited in the literature that attribute to unsuccessful implementation of not only science curriculum reforms and also the educational reforms. These include the following: Teachers need to have sufficient skills and knowledge to be able to practice their roles in a pre-determined way. Therefore, in-service training on the new curriculum is necessary before implementation and the new curriculum needs to be incorporated in the teacher training program at teacher institution of higher learning. If any problems occur in practice, then they have to solve these so that they can provide the learners with equal learning opportunities by which their pupils can be educated in relation to the needs of the country (Ekiz, 2004). Structurally, teachers have to deliver more economical and efficient curriculum-related structures (Graham-Jolly, 2003). Culturally, they have to prepare
pupils for what the society needs. Curriculum change is accompanied by different stages and challenges. The introduction of a new curriculum poses a range of challenges to teachers with regard to the underlying assumptions and goals, the subject demarcations, the content, the teaching approach and the methods of assessment (Snyder, 1992). Teachers are the key point in the curriculum reform process, they have to be sufficiently trained and equipped in order to implement the new curriculum. One of the major hindrances within the educational reformation process is an existing gap between theory, that is, policy and practice, that is, implementation. Putting ideas on paper have been one of the cornerstones of Zimbabwean policy, but transforming these ideas into practical realities has met resistance from various sectors such as the Ministry itself, parents and teachers. In all honesty, most of these reasons are teacher related.

Essentially, this research endeavours to find out the science teachers’ conceptions of STEM teaching and learning. This research will be limited at focusing on science teachers and their contribution to the success of the STEM initiative. The encouragement science teachers give to learners to take STEM learning areas, their training background and understanding of STEM will be key factors for the long run success of the whole STEM initiative.

1.2 Statement Of The Problem

STEM teaching and learning herein referred to as ‘stemitising’ science education in Zimbabwe comes from a background of many either failed and/or abandoned reforms as discussed above. One of the main impediments to the successful implementation of earlier reforms widely revealed in the literature is teachers’ limited understanding of what these reforms were demanding from them. These include content, pedagogy, resources and disposition problems. All these basically, are rooted in subject-specific training that these teachers were subjected to. This implies that the pedagogical content knowledge [PCK] that they hold does not support STEM integrated teaching and learning. Subject-specific training leads to separatist teaching and learning approaches. In other words, these teachers hold hard science subject content that is scientific discipline based such as physics, chemistry and biology. Yet content is a pre-requisite to pedagogy that makes students understand what the teacher will be teaching. No wonder why since the introduction of the STEM curriculum most teachers have maintained their traditional separatist teaching approaches. It is most likely that these teachers subject-specific training are short of what STEM content to teach and how to teach it. To worsen these
challenges is that the STEM education reform has been introduced without accompanying guiding frames and teaching resources. But how limited their STEM teaching and learning knowledge can never be known if research of their conceptions of this reform is not conducted. Such type of research is scarce in the literature. If such researches are not undertaken, then the extent of the science teacher’s knowledge of STEM teaching and learning cannot be ascertained. Measuring the limitation of the science teacher’s knowledge of STEM teaching and learning will enable policy makers in developing mitigation measures in order to assist or cover the gaps for a successful implementation of the STEM education reform. This study is, therefore, undertaken to find out the Masotsha High School in the Khami District schools science teachers’ conceptions of STEM teaching and learning. It is informed by the following research questions.

1.2.1 RESEARCH QUESTIONS

The following research questions (RQ) guided this study.

RQ1: What does STEM mean to the science teachers at Masotsha High School?

RQ2: How do these teachers comprehend STEM Education in relation to STEM?

RQ3: How do these science teachers interpret the new STEM curriculum?

These RQs were converted to research objectives (ROs) in order to get a clear focus of the study purpose.

1.2.2 RESEARCH OBJECTIVES

The objectives of the study were to:

RO1: understand the meaning Masotsha High School science teachers attach to STEM.

RO2: establish how these teachers comprehend what STEM Education is in relation to STEM.

RO3: describe how these teachers interpret the STEM curriculum document.

Many stakeholders of science education in Zimbabwe and beyond are likely to benefit from achievements of these objectives as discussed in the ensuing section.
1.3 **SIGNIFICANCE OF THE STUDY**

This research may assist in informing STEM education stakeholders in identifying hindrances to the implementation of the STEM program and also come up with solutions to arising problems.

The findings of the study may benefit students, teachers, heads of schools, educational inspectors and curriculum designers in informing them on the science teachers’ conceptions of STEM teaching and learning. To the teacher it will benefit in improving comprehension and understanding of the STEM curriculum. The teacher in turn may motivate students and develop a love for STEM subjects in them. A knowledgeable and well-motivated teacher might benefit the students in fostering a positive attitude and the appreciation of STEM learning areas which will be translated into high pass rates among students. The heads of schools may benefit in that it will inform them of the lack of resources in successfully implementing the new STEM curriculum whereas the education inspectors may be informed on the type of workshops that can be implemented in order to cover the gap in lack of content or knowledge by the science teachers. The research will also assist curriculum designers in planning ahead and on the importance of involving all stakeholders in curriculum planning and design for the successful implementation of future curriculum reforms.

The research may also benefit researchers pursuing similar studies on the factors affecting science teachers’ conceptions of STEM teaching and learning with a view of making STEM teaching and learning more beneficial and effective.

1.4 **ASSUMPTIONS**

It is assumed that science teachers’ conceptions of STEM teaching and learning is poor due to poor implementation of the new STEM curriculum by the policy designers. The following assumptions are established about the study:

- Lack of understanding on the meaning science teachers attach to STEM.
- Extent of comprehension by science teachers of what STEM Education is in relation to STEM.
- Extent of interpretation of the new STEM curriculum document by the science teachers.
1.5 **DELIMITATIONS OF THE STUDY**

This study was delimited in three main ways: These are study location, conceptual focus and the methodology adopted. These are discussed in turn as follows.

1.5.1 Geographical location

The research was conducted with the science teachers at Masotsha High School in the Khami District in Bulawayo Metropolitan Province.

1.5.2 Conceptual focus

Three key terms: (1) science teachers, (2) STEM teaching and learning and (3) teachers’ conceptions formed the conceptual boundaries of this study.

1.5.2.1 Science teachers

These are trained members of the teaching profession specifically in the sciences such as physics, chemistry, biology, combined science, mathematics, agriculture, geography, computer science and so on. The National Science Teachers Association (2003) in the United States of America defined a science teacher as a teacher with the necessary knowledge and planning skills to achieve teaching and learning goals, but also that they are successful in engaging their students in understanding the relationship of science and technology, nature of science, inquiry in science, and science-related societal issues.

1.5.2.2 STEM teaching and learning

Dugger (2010) defines STEM teaching and learning as a more comprehensive way of fusing all four disciplines into each other and teach them as an integrated subject matter. STEM teaching and learning is an integration of the four subjects, science, technology, engineering, and mathematics. STEM teaching and learning entails knowledge, skills and beliefs that are collaboratively constructed at the intersection of more than one STEM subject area.

1.5.2.3 Teachers’ conceptions

Pratt (1992) defines teachers’ conceptions as specific meanings attached to phenomena which then mediate our response to situations involving those phenomena. We form conceptions of
virtually every aspect of our perceived world, and in so doing, use these abstract representations to delimit something from, and relate it to, other aspects of our world. In effect, we view the world through the lenses of our conceptions, interpreting and acting in accordance with our understanding of the world. Ho et al. (2001) claims that a teacher who conceives of teaching as the transmission of information is likely to employ teacher centred strategies in order to operationalize that conception. Therefore, conceptions are attitudes, perceptions and beliefs towards the teaching and learning of STEM learning areas.

1.5.3 Methodology Adopted

This study adopted a case study design grounded in the qualitative approach to research.

1.6 LIMITATIONS OF THE STUDY

The research was carried out during the school holidays, therefore, the researcher used all the time available to conduct interviews since most teachers were located at their homes, except for combined science and chemistry teachers who had their teacher generated documents with them. The acquisition of teacher generated documents from other teachers was delayed due to the Easter holidays. To minimise this delay the researcher proceeded in the analysis of the new curriculum documents at the same time carrying out the first interview sessions with chemistry and combined science teachers. The study was not able to control the inconsistencies that came up due to different responses by participants, however, the participants were free to use any language they felt comfortable with.

1.7 CHAPTER SUMMARY

This chapter introduced this study. It discussed the background of the study, the problem under study that is inclusive of the statement of the problem, research questions and objectives, significance of the study, assumptions of the study, delimitations of the study that incorporates the geographical setting of the study, the conceptual parameters and methodology adopted and limitations of the study. The next chapter will focus on the literature review looking specifically at chapter introduction, science education reforms, STEM education, teachers as curriculum reform agents, theoretical frames such as meta-cognition and conceptual change.
CHAPTER TWO: LITERATURE REVIEW

2.0  INTRODUCTION

This chapter presents and discusses the literature reviewed related to the teacher’s conceptions of STEM teaching and learning. It does so from the two main understandings of what literature review entails. First, that it [literature review] focuses on what has been written by other researchers related to the study being undertaken (Miler, 2003). Secondly that it involves evaluation, critical analysis, and presentation of a segment of a body of knowledge published prior to the problem being investigated (Boyatzis, 1998; Sprintall, 2003). Reviewing of literature assists the researcher to understand research topic more, and reveals the gaps in literature that the current study hopes to fill. The chapter organised around four themes: (1) science education reforms in Zimbabwe, (2) STEM education in Zimbabwe, (3) teachers as curriculum reform agents and STEM teaching, and (4) research frameworks. The chapter concludes with a summary of the main issues raised.

2.1  SCIENCE EDUCATION REFORMS IN ZIMBABWE

The abstract nature and complexity of science has by and large contributed to students’ negative attitudes towards the learning of science (Piburin, 1993). The learning of science related subjects, demotivation is another factor closely linked to the complexity nature of science and students’ negative attitudes towards science related subjects and their learning (Mamlok-Naaman, 2005). Such attitudes have seen nations globally grappling with the issue of how to boost the dwindling enrolments of science related subjects in educational institutions across all levels (Piburin, 1993). Reforms in science subject related programmes or curricula has therefore been acknowledged as the only way to counter the learning of science related subjects challenges which in turn is envisioned to boost enrolments in educational institutions.

The emphasis on science education and its reforms is recognised for its socio-economic development and growth of nations. To date, Southern African Development Community (SADC) has produced “…a draft Regional Industrialisation Strategy and Roadmap that provides a framework for major economic and technological transformations at the national and regional levels within the context of deepening regional integration” (Ngwawi, 2015). Its
primary aim is the attainment of industrialisation, regional integration and economic competitiveness through exploiting the comparative and competitive advantages of the region (Ngwawi, 2015). SADC nations including Zimbabwe are fully aware that this industrialization goal can only be fully achieved by a strong science education foundation for science and technology which underpins economic development.

Dzingai Mutumbuka the first Minister of Education and Culture, in criticizing the colonial era government stated that: There is little relationship between what is learnt in school and real life problems. A yawning gap separates theoretical knowledge from its practical application (Zimfep, 1991).

This mind-set helped in promoting the concept of education with production where its main focus was the promotion of collective activities and establishment of co-operative projects at schools; the creation of a new mentality wherein learners are conscientised to appreciate manual labour, understand the production process and develop the learners into worker intellectuals; the promotion of socialist values such as equality, respect for human dignity, cooperation, social responsibility, self-reliance, respect for creative labour and collective development and the integration of schools and local communities (Nhundu T. a., 1993). Some of these values are still being revived in the promotion of the new STEM curriculum in order to drive the industrialisation process where innovation, self-reliance, critical thinking and problem solving skills are being promoted. Science exhibition competitions are held at primary and secondary levels, where, students use scientific knowledge learned during lessons to produce ideas or gadgets that solve everyday problems in the real world. In the [science exhibition] competitions held annually in all provinces throughout Zimbabwe, there is an encouragement in the development of new ideas. The new STEM curriculum equips students with knowledge and skills that are necessary for self-reliance.

The history of education with production lies in the belief in trying to solve the pressing issues the liberation fighters faced whilst they were in Mozambique and Zambia such as shortage of food and accommodation (Nhundu T. a., 1992). It is documented that:

Production was integrated into the lessons with students building their own barracks and classrooms, making their desks and benches, growing their own vegetables,
digging pit latrines and being generally responsible for their camp welfare (Zimfep, 1991).

Education with production was carried over after independence and had the full support of the then Minister of Education and Culture, Mutumbuka. He [Mutumbuka] noted that:

We could not make major changes on national scale without a preparatory phase of experimentation and planning. Before we launch a new system, a lot of spadework must be done. We need to draw up an entirely new curriculum, to write new textbooks, to train a new type of teacher and to convince parents and Ministry officials to accept changes. Zimfep is [an important] instrument that can do that spadework. It has the flexibility and the freedom to try out new things and to make recommendations to [the] Ministry based on the experiments it is conducting in eight pilot schools throughout the country. These schools are laboratories for change where new ideas can be tested. We are not starting from scratch since we have already established a more solid foundation in the liberation schools that were set up during the struggle (Mutumbuka, 1984).

The minister was highlighting the procedures for drawing up a new curriculum that had various stages such as training teachers, writing new textbooks, changing the mind-set of the parents, education practitioners and officers at the same time acknowledging the fact that the program was not starting from scratch but had a solid foundation as it was practiced during the liberation struggle. The idea behind STEM can be directly compared with education with production. Think tanks within this Ministry of Higher and Tertiary Education, Science and Technology Development (MHTESTD) are wholly convinced that STEM provides the right environment for the development of invaluable skills and knowledge such as leadership, critical thinking, problem solving, creativity, communication skills, team work and conflict resolution (MHTESTD, 2016). Skills, such as these, are seen as critical in the socio-economic reformation of the country and should, therefore, be harnessed among students.

The main objectives of ZIM-SCI were:

To develop low-cost, high local content science kits, thus encouraging the use of local resources, reducing the use of [scarce] foreign currency, cutting costs of teaching science and making it possible to give all children a high quality, practical and relevant science education; to emphasize hands-on, student-centred teaching, developing a scientifically literate population, encouraging students to approach scientific problems
critically and developing an aptitude to resolve problems; to enable relatively unqualified science teachers to teach science competently; to provide a curriculum which makes secondary school syllabuses more appropriate to Zimbabwe, making the science part of the students' everyday experiences (Musar, 1993).

These objectives are easily comparable to the new STEM curriculum were student activity-based teaching and learning are encouraged, students learn through practical activities, teamwork, cooperation and engaging in projects related to the STEM subject. An aptitude in problem solving and critical thinking skills are the main cornerstone in the new STEM curriculum. Where, there is a lack of resources, improvisation is encouraged so that learners can think outside the box. The students’ imagination is not constrained by the lack of resources in their schools.

Introduction of tech-voc teaching and policies on compulsory teaching of sciences and mathematics. Lauglo and Lillis (1988) define vocationalization of education as curricular change in a practical or vocational direction, which is taken to mean the:

Inclusion in the curriculum of practical subjects which are likely to generate among students some basic knowledge, skills and dispositions that might prepare them to think of becoming skilled workers or to enter some manual occupations (Bacchus, 1988).

Bacchus (1988) further broadened the definition of vocationalism as:

Diversification of education, sometimes with the cooperation of industry, by the inclusion of practical subjects into what has hitherto been an essentially academic curriculum, with the specific aim of either orienting learners towards manual work or giving them skills usable in future employment or self-employment.

Technical education is taken to mean “formal education designed to provide knowledge and skills underlying production processes with a wider connotation than vocational education”, which takes place in colleges of further education or universities (Lunga, 2000). It is, however, not uncommon to find students receiving both technical and vocational education at the secondary level. Education such as this has a dual purpose, “that of preparing the learner for the world of work and that of progressing to tertiary level” (Motsi, 2014). That is where the new STEM curriculum comes into place as it seeks to offer skills and knowledge to the learners that are necessary in industry and commerce, and for self-reliance. Chitate (2015) summarised
the specific provisions for vocational and technical skills development at secondary level in the proposed Zimbabwe education system in points, thus:

i. Initial development of all-round basic skills encompassing manipulative, computer, maths, civic, science, social, and language skills among Grade 1 to 9 pupils. Assessment at this basic education level will involve guidance and counselling, mini projects and tests (Nziramasanga, 2014).

ii. Establishment of General (academic), business/commercial, technical, and vocational tracks for Senior School 1 students. “At the end of the Senior School I (year 11) pupils sit the first public examination, the General Certificate of Education, which may be categorised as GCE (Nziramasanga, 1999); and

iii. In the Senior School 2, the General track students will take three ‘A’ Level academic subjects in preparation for tertiary education while those in the skill-tracks study for National Diploma Certificates (NDC) in their areas of specialization, “which will be considered the equivalents of A level for University entry” (Nziramasanga, 2014).

Hence, the introduction of practical, investigative tasks and projects in the new STEM curriculum. This is an attempt by the Ministry of Primary and Secondary Education [MoPSE] to develop an all-round basic skills encompassing manipulative, computer literate, science and mathematics student. This [STEM] student is able to adapt to the current demands of industry and commerce.

Integration of Indigenous Knowledge with school science is important in order to prevent a cultural clash whenever students attempt to learn meaningful school science (Aikenhead, 2001). Science education has to be identified in students’ culture in order for it to be relevant to them. Emeagwali (2003) further reinforces this point by stating that a science curriculum that is responsive to Indigenous Knowledge enables sustainable development, environmental responsibility, and cultural survival. However, less resources have been directed into this endeavour, leaving the integration of indigenous knowledge to the science teacher who in most cases is poorly trained and lacks relevant resources such as textbooks to link indigenous knowledge with science. The secondary school science in Zimbabwe is a legacy of the British colonial education system which tends to ignore or not adequately respect or acknowledge the contradictions between students’ private or public lives (Shizha, 2005). The secondary school curriculum does not cover indigenous knowledge as it focuses on western science in its purest
form. Hence, incorporation of indigenous knowledge into the STEM curriculum will mostly be dependent on how science teachers perceive indigenous knowledge. This will provide information that will guide science teacher educators and supervisors to plan for effective curriculum reform in view that teachers are the key to any curriculum change endeavour; they can make or mar any of its curriculum no matter the quality of its design or content (Ogunniyi, 2005). Therefore, the integration of indigenous knowledge with science will depend on the science teachers’ perception of indigenous knowledge relative to science teaching and learning.

Science kit based teaching is inseparable from STEM teaching and learning in Zimbabwe, since most schools in the rural areas lack proper laboratories or mobile laboratories and the funds to purchase them. It [Science kit based teaching] needs to be developed extensively in order to cater for the less privileged STEM students who are mostly found in the remotest parts of the country. It [Science kit based teaching] was used during the ZIM-SCI period in order to bring science learning to all secondary schools (Musar, 1993). According to Musar (1993), financial problems in the school system expansion appeared to be insurmountable, therefore, the provision of laboratories and standard science equipment was out of the question, but the Ministry of Education and Culture wanted science to be compulsory for all students at the secondary level. They became interested in Distance Science Teaching Unit (DIST), a project for distance education, developed from 1978 by Alan Dock and his colleagues in the Department of Curriculum Studies at the University of Zimbabwe (Musar, 1993). The distance teaching system had five basic components:

- A mentor in charge of a study group, audio cassette player, study guide for each learner,
- A basic kit of low-cost apparatus for each learner, and consumable materials, carefully calculated to meet the needs of the unit of study. (Musar, 1993).

This science kit enabled every student to learn science in all the parts of Zimbabwe. This concept of science kit based teaching can also be incorporated in STEM teaching and learning to cater for the disadvantaged students. This will help in bringing STEM teaching and learning to all parts of Zimbabwe and at the same time eliminating the excuse of a lack of chemicals, apparatus, textbooks and laboratories as the reason for not taking up STEM related subjects by schools and students.
The introduction of STEM education reform is needed so that students can understand and be capable of using skills and concepts developed through STEM education to be active citizens, to engage with modern communication and media to ensure personal well-being and to make informed choices about many aspects of their lives. It [STEM education reform] is relevant for economic and industrial development. Students’ science attitudes affect their interest in science related carriers. A decline in students’ attitudes towards studying science has led to a “swing away from science” in many countries (Osborne J. S., 2003). To better fulfil the needs of a knowledge based economy industries, enrolment in STEM learning areas needs to be increased (Dagher, 2011). It [STEM education reform] is needed in order to change the mind-set of the students, parents, education practitioners and officers and gear them towards a STEM driven economy and industry. The STEM curriculum itself needs to reflect the prevailing economic situation for it to be relevant. STEM education includes the knowledge, skills and beliefs that are collaboratively constructed at the intersection of more than one STEM subject area (Corl, 2014). STEM learning areas need to be integrated.

2.2 **STEM Education**

The construct STEM education is compounded from two words: STEM and Education. The meaning of the term STEM has revolved over years. In the early stages, it [the term STEM] related to the revolutionary technologies used to produce gadgets such as the light bulb, automobiles, tools and machines among others by engineering firms. Many of the people responsible for these innovations were only slightly educated and/or were in some type of apprenticeship. For example, Thomas Edison who invented the phonograph, electric light system and a system of power plants through engaging in a various experiments through persistence and diligence, did not attend college (Beals, 2012). From this conception of STEM, it entails that the primary concern of STEM was oriented towards practical application of science related concepts (science, technology and mathematics). No wonder most scholars like Reeves (2002) defines STEM simply as Science, Technology, Engineering and Mathematics.

STEM is more than just the mere teaching of Science, Technology, Engineering and Mathematics. Rather, it is the systematic unpacking and application of these knowledge bodies premised on scientific principles underlying the systematic resolution of human’s everyday life-problems, needs, and wants (Gandawa, 2016). It entails scientific knowledge production and its application in technology and engineering fields. STEM is seen as the panacea in
resolving human needs and wants, and also ingrained in human activities. Engineering is defined as knowledge of mathematics and natural sciences acquired through study, experience, and practice and applied to utilize economically the materials around us and forces of nature for the benefit of mankind (Atkinson, 2007). Engineering essentially involves applied mathematics and science in order to harness natural resources into useful products. According to Hudelson (1994) technology is defined as the ability to responsibly use appropriate technology to communicate; solve problems; and access, manage, integrate, evaluate, design, and create information to improve learning in all subject areas and to acquire lifelong knowledge and skills in the 21st century. They further state that technology is the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities (Hudelson, 1994). Technology combines scientific and engineering knowledge in order to solve everyday problems for the benefit of mankind.

From the definitions of STEM, engineering and technology it can be seen that STEM plays a major role in socio-economic development and growth of man. The need and demand for a workforce with STEM-related skills will increase with time and are one of the requirements to resuscitate our economy and industries in Zimbabwe (Parawira, 2016). The resuscitation of industries in Zimbabwe will see a demand of individuals with STEM related subjects for the industry to be competitive regionally and internationally. Professor Wilson Parawira is further quoted:

Graduates of STEM-related degrees are expected to [be] creativity driven, project oriented, understand all stage[s] of invention including ideation and development and have the ability, courage to set up high-tech enterprises. Students are exposed to entrepreneurial and/ or ‘technopreneuralship’ courses. Basically at these levels STEM education promote[s] innovation, wealth creation and entrepreneurship (Parawira, 2016).

STEM will be able to change the socio-economic structure of Zimbabwe as the STEM graduates will be geared towards carriers that are basically economic drivers. Setting up high-tech industries will also create employment for other STEM graduates and the monetary incentives will in turn benefit the families of these individuals and other line and related industries that will be supplying components for these tech-companies.
Education as implanting a will and facility for learning; it should produce not learned but learning people (Lloyd-Yero, 2002). In line with this definition, Ayn Rand in Lloyd-Yero (2002) states that:

The only purpose of education is to teach a student how to live his life-by developing his mind and equipping him to deal with reality. [The student] has to be taught to think, to understand, to integrate, [and] to prove. …be taught the essentials of the knowledge discovered in the past and he has to be equipped to acquire further knowledge by his own effort.

The articulation of education above entails that it involves equipping learners with knowledge, skills and attitudes that enable them to meaningfully participate in national and international socio-economic development activities. Thus, education develops the whole person so that the individual can function in society. An educated person can transform theory into practice, therefore, a permanent change must be observed in one’s life. In other words an individual is taught critical thinking and problem solving skills.

A simple definition of STEM Education can be derived from the combination of the meanings of STEM and education. Thus it is the capacitiation of the learner with knowledge, skills and positive attitudes of STEM. However, literature present on how people define what STEM Education is diverse. Some people understand STEM education as the mere teaching of STEM related subject such Biology, Geography, and Mathematics and so on. Others understand it from its abbreviation point of view as the teaching of Science, Mathematics, Engineering and Technology (SMET) in educational institutions. This understanding can be traced from the origins of the term STEM created by the National Science Foundation (NSF) (Sanders, 2009) (SMET). This definition carries a subject matter knowledge (content) emphasis. Thus, the teaching and learning of content related to science related subjects, technology, engineering and mathematics. It carries what ought to be taught meaning. Another category of people attach a pedagogical meaning to STEM education, that it is an integrative teaching and learning approach of concepts drawn from one or more STEM disciplines (Wang, 2011). STEM education encourages interdisciplinary knowledge and skills that are relevant to life and prepare students for a knowledge-based economy (NRC, 2011). Pedagogically, it is the teaching and learning of concepts drawn from the fields of science, technology, engineering, and mathematics across all educational levels (Gonzalez, 2012) In this regard, Goldin (2003); Seymour and Hewitt (2000); Singh et al. (2002) note that science related subjects (e.g
chemistry), technology, engineering and mathematics are closely related as such STEM courses and programs should be developed to generate meaningful learning through integrating knowledge, concepts and skills systematically.

Every nation including Zimbabwe is working hard to develop a STEM literate society within its boundaries and beyond. These efforts emanates from the perceived individual, national and international socio-economic development and growth benefits derived from STEM literacy. STEM literacy entails the ability to identify, apply and integrate concepts from science, technology, engineering and mathematics to understand and develop solutions to a variety of complex problems and to innovate and solve them (Zollman, 2012). At an individual level, STEM literacy at school and college levels channels individuals into STEM related careers that provide such products with immediate employment and high salary opportunities. This assertion is supported by Rothwell (2013) who quotes the United States Department of Commerce Economics and Statistics Administration and says:

STEM occupations are projected to grow by 17.0 percent from 2008 to 2018, compared to 9.8 percent growth for non-STEM occupations…STEM workers command higher wages, earning 26 percent more than their non-STEM counterparts…More than two-thirds of STEM workers have at least a college degree, compared to less than one third of non-STEM workers…STEM degree holders enjoy higher earnings, regardless of whether they work in STEM or non-STEM occupations.

STEM education reform initiatives were introduced in many nations the world over because its stakeholders strongly believe that the foundations of a STEM literate society are laid in teaching and learning of sciences. These disciplines capacitate learners with critical thinking skills and creativity as well as developing positive attitude towards sciences and their learning which are good ingredients for innovative thinking. Innovation involves the integration of diverse STEM skills and transcends disciplines and is a highly interactive and multidisciplinary process or product that rarely occurs in isolation and is tightly connected to life (OECD, 2010a). STEM learners whilst still in schools, colleges and Universities acquire diverse knowledge and such knowledge is needed for their uptake of STEM related careers in the future (Bybee, 2013). At national and international levels, it has been argued that STEM related careers are the cornerstone of Science and Technology for socio-economic development (Kuenzi, 2008). Zimbabwe likewise has joined the recognition that scientific literacy is her cornerstone of socio-economic development by putting in place the ZimAsset plan (Matutu, 2014). Science,
Technology and Innovation (STI) policy (Tsvangirai, 2012) and STEM education reform posit that the ZimAsset’s mission is to provide an enabling environment for sustainable economic empowerment and social transformation for the people of Zimbabwe (Chitate, 2016). Both the STI and STEM education reform direct the Education ministries, Primary and Secondary Education (MoPSE) and that of Higher and Tertiary Education, Science and Technology Development (MHTESTD) “to re-align their training programmes in order to produce cadres, in sufficient quantities and high quality, to effectively translate the Policy into practical actions for concrete outputs and outcomes” (Tsvangirai, 2012). In January 2016, the Ministry of Primary and Secondary Education rolled out the new STEM curriculum at Advanced level (Chitate, 2016).

Notwithstanding the benefits of STEM Education, it is worth noting that the introduction of these reforms in all the nations comes against the preceding problem of dwindling enrolments in STEM related subjects in colleges and universities (Rumberger, 1987). Chitate (2016) states that in Zimbabwe, STEM education reform was born out of the realisation that there was a noticeable decline, in the candidature of pupils who took pure sciences at “A” level:

...leading to low enrolments in STEM at University level. It is estimated that less than 17% of the total enrolment in Zimbabwean Universities are in STEM related disciplines with the majority being in commerce and social sciences, a situation that cannot adequately support the value addition and beneficiation of our natural resources in order to effectively extend product value chain as the nation prepares for our envisaged national knowledge economy (MHTESTD, 2016).

Underlying such enrolment trends are reasons such as the complexity of the subject matter that leads to learners developing negative attitudes towards the subjects and their learning and loss of interest. Such problems arise when the subjects are taught separately. These problems are likely to worsen when the STEM related subject content is integrated. Logically, the STEM content becomes deeper and more challenging. To make matters worse, the teachers in most schools have been trained in specialised subject teaching. This is separatist and traditional teaching of science subjects. So such teachers may be to a greater extent limited on what STEM content to teach and how to teach it (Mpofu & Vhurumuku, 2017). Moreover, the STEM education reform has been introduced in Zimbabwe without accompanying guiding frames and teaching resource. Above research related to STEM education in Zimbabwe is very few as the subject is still relatively in its infancy.
To inform STEM classroom practices, the study focuses on science teachers’ conception of STEM teaching and learning at Masotsha High in the Khami District in Bulawayo Metropolitan province. Its findings are envisioned to provide insights into the conception and implementation needs science teachers are in need of to successfully implement the STEM education reform. This is because this study recognises that teachers are critical agents of any curriculum reform.

2.3 **Teachers as Curriculum Reform Agents and STEM Teaching**

The term curriculum is a multifaceted concept (Goodson, 2003). One all-embracing definition of curriculum proffered by Harrison & Treagust (2006) is: it is the sum of learning experiences offered by schools. It calls for decision making and describes curriculum towards accomplishment of set educational goals and complexity of educational decision making (Seymour, 2000; Shao-Wen, 2012). Such decisions are made at both curriculum development and implementation levels. Literature on curriculum change espouse that teacher involvement at development level is most likely to raise chances of the successful implementation of a reform (Dori, 2002). This views teachers as critical agents of curriculum change and know learners’ experience and more needs than anyone else in the system, and are in a position to apply what is locally relevant and implement, with devotion, programmes they have designed or chosen themselves (Moyo W., 2013). In this regard, teachers ought to be regarded as an integral part of the curriculum development process rather to be seen as mere translators of other people’s intentions and ideologies into practice (Clandinin D. &., 1986).

Embracing change is a mental process and activity. The introduction of STEM teaching and learning in Zimbabwe is science curriculum reform that demands mental processing. Thus, the STEM curriculum implementation success heavily lies with how teachers interpret the new curriculum documents and what these teachers teach in science classrooms. The teachers’ interpretations of the new curriculum documents heavily hinges on their cognition. The oxford dictionary defines cognition as the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses. The variation of human cognition in relation to a new encountered phenomenon lead to different levels of perceptions, attitudes and understandings. This provides a possible explanation as to why Moyo (2013) espouses that the implementation of the STEM curriculum in Zimbabwe was being hindered by the unsupportive teaching environment, teachers’ negative attitudinal disposition, their limited
STEM content and pedagogy as well as lack of resources and guidelines to implement it. Poor science teacher conceptions of STEM teaching and learning can discredit the adoption of this educational revolution.

Teachers as curriculum interpreters and implementers exercise professional judgment about the ways they make sense of the curriculum (Jansen, 2003). Yet, more than often these teachers are ill equipped to implement curriculum paradigm shifts (Avalos, 2002; Carl, 2002; Dori, 2002). Notably, most curriculum implementation efforts fail because curriculum leaders neglect to provide adequate staff development opportunities (Czajkowski, 1980). Without sufficient training and support, even teachers initially enthusiastic about an innovation may become frustrated by implementation problems, turn against the project and revert to the security of their previous teaching methods (Czajkowski, 1980). “The empowered teacher will probably not regard the learning area or subject as a recipe from which one may not deviate, but rather as an opportunity to experiment and to make it relevant and meaningful” (Carl, 2002). Capacitation of teachers to successfully perform their new roles in the design, implementation and evaluation of a new curriculum therefore needs no emphasis (Carl, 2002). Logically, the capacitated teacher will be motioned to effect curriculum change agent (Cuban, 1990).

In respect of the successful implementation of the STEM curriculum, who teaches in STEM programme matters (Pasametier, 2011). In order to have a STEM implemented class, teachers need to hold certain skills and knowledge so that they can integrate technology and engineering concepts into their classroom practices (Zarske, 2004). Yet research elsewhere has shown that many teachers are under-qualified to teach STEM subjects (Ejiwale, 2013). In Zimbabwe, qualified and experienced STEM related subject teachers have migrated to other nations in search of better economic condition (Mpofu V. S., 2012; Asante, 2012). This has left the country with a serious shortage of competent STEM related subjects teaching professionals. This assertion lands support of Gadzirayi et al (2016) who in their study on the status of STEM in Zimbabwe revealed that the country is largely drawn back by a critical shortage of STEM teachers. Significant to the Zimbabwean situation is Thomasion’s (2011) study that notes that America is lagging behind other developed countries in STEM because of lack of qualified mathematics and science teachers. Thus, the focus of this study on teachers’ conception of STEM teaching and learning becomes relevant in that it serves as a diagnostic survey that will inform teachers’ STEM implementation capacitation programmes.
2.4 **THEORETICAL FRAMEWORK**

Theoretical framework are structures refers to a theory or theories that inform the study in terms of conceptual and theoretical decisions as well as methodological choices (Mpofu V. M., 2014). This definition informed my choices of theories and blending them into its theoretical framework. The theories of conceptual change and meta-cognition were blended into a theoretical framework for this study.

2.4.1 The theory of meta-cognition

Critical to effecting a curriculum change is the implementer’s level of cognition about the change and its benefits. Cognition determines the degree to which teachers choose to accept or reject change (Wallace, 2005). “Metacognition is a variant of cognition which refers to awareness and management of one’s own thought about an issue such as STEM teaching and learning” (Kuhn, 2004). It [metacognition] monitors and controls a person’s thoughts about an issue (Martinez, 2006). In addition, metacognition enables a learner to transfer and apply problem solving strategies taught in one context to a new context (Kuhn, 2004). In teaching and learning metacognition instruct the teacher to monitor self-ideas in comprehending and performing curriculum tasks, planning and implementing classroom practices, and evaluating self (Rothwell, 2013).

Metacognition has two main parts: (1) knowledge about cognition and (2) monitoring of cognition (Schraw, 2006). Cognitive knowledge or knowledge about cognition relates to one’s understanding of his or her own cognitive strengths and limitations, including both internal and external factors that may interact to affect cognition (Flavell, 1979). Monitoring of one’s cognition, activities of planning, monitoring or regulating, and evaluating (Whitebread, 2009). Planning involves identifying and selecting appropriate strategies and putting in place enough resources. This includes the setting of goals, activating background knowledge, and allocating enough time. Monitoring involves attending to tasks and having an awareness of comprehension and task performance and this can involve self-assessment. Last but not least, evaluation is defined as appraising the products and regulatory processes of one’s learning, and includes revisiting and revising one’s goals (Schraw, 2006).

Four states: (1) meta-memory, (2) meta-comprehension, (3) critical thinking and (4) problem solving are involved in metacognitive functioning (Martinez, 2006). The first state of meta-
memory relates to one’s understanding of his or her own knowledge state as a basis for future learning. Secondly, meta-comprehension has to do with one’s comprehension ability from listening and reading. The third aspect of critical thinking involves evaluating ideas for their quality and lastly problem solving relates to one’s ability to pursue a goal on uncertain circumstances.

This theory teaches us that people possess different levels of cognition. This leads us to understand that different science teachers may hold varied understanding of what STEM teaching and learning entails. Understanding the different meanings teachers attach to STEM teaching and learning therefore is an important precursor their professional development needs for successful implementation of the new STEM curriculum in Zimbabwe.

2.4.2 Conceptual Change Model

Effecting a curriculum change is a cognitive demanding process and activity. It requires the teacher to acquire and be positioned as a learner. With regards to the new STEM curriculum, the teacher encounters new STEM content that requires a pedagogical shift from the subject specific based teaching methods to that of STEM integrated approaches. Hence the concept of conceptual change is pivotal to the teachers’ learning of STEM content and pedagogy. Vosniadou (2007) defines conceptual change as how learners learn to restructure their naive, intuitive theories based on everyday experience and lay culture. This assertion is in line with the view that learning basically involves changing a person’s conceptions in addition to acquiring new knowledge to what is already there. It is grounded in the ideals of the role of learners’ prior knowledge in learning new concepts in order to bring out change in conception of encountered phenomena (Vosniadou, 2007). Further, conceptual change is closely related to the growth of an awareness of the diversity and tenacity of students’ views of natural phenomena (Hewson P. W., 1992).

The above view of conceptual change are embodied in conceptual change models (CCM) of learning, see (Posner, 1982; Hewson P. W., 1982; Hewson P. W., 1981). The models capture learning as involving an interaction between new and existing conceptions with the outcome being dependent on the nature of the interaction. Two major components of the CCM. are: (1) for a person to experience conceptual change there are conditions that need or no longer need to be met and (2) the person’s conceptual ecology provides the context in which the conceptual change occurs influences the change and gives it meaning. The conceptual ecology consists of
many different kinds of knowledge. These include, epistemological commitments, metaphysical beliefs about the world and metaphors that might serve to structure new information. Thus any person positioned as a learner uses his or her existing knowledge (i.e. their conceptual ecology), to determine whether different conditions are met, that is whether a new conception is intelligible (knowing what it means), plausible (believing it to be true), and fruitful (finding it useful) (Hewson P. W., 1992). If the new conception is all there, learning proceeds without difficulty. Metaphorically this relates to knowledge as extended just as in extending a house by additional well thought out structures which will be consistent with the existing structure. Of course, the additional renovations changes the outlook of the house.

There is also the relationship between status change and conceptual change (Hewson P. W., 1991). Hence, CCM predicts that conceptual changes do not occur without concomitant changes in the relative status of changing conceptions. Learning a new conception means that its status rises. That is, with regard to the understanding the new STEM curriculum the teacher-learner understands it, accepts it, and sees it as useful. Consequently the teacher-learners needs to view the STEM curriculum as of higher status as compared to current science curriculum. According to the CCM, the teacher-learner only embraces curriculum change if the teacher-learner holds that the new STEM curriculum conception is of considerable value. It is the learner’s conceptual ecology that plays a critical role in determining the status of a conception. This is because it by and large provides the criteria for his or her judgement on whether a given condition is or is not met.
2.4.3 An integrated conceptual change and meta-cognition theoretical framework

Figure 2-1 below integrates the meta-cognition and conceptual change into a theoretical framework for this study.

![Diagram](image)

**Figure 2-1:** The blended meta-cognition and conceptual change model

Figure 2-1 depicts that studying teachers’ conception of STEM teaching and learning is bounded within the theories of meta-cognition and conceptual change. This integrated model provides us with the parameters of understanding how teachers comprehend the STEM teaching and learning. These are (1) cognition knowledge of STEM and STEM teaching and learning, (2) monitoring of their understanding and (3) interpretation of STEM teaching and learning, (4) their ecological and conceptual change conditions that might hinder or (5) support their paradigm shifts from subject specific pedagogy and (6) content to STEM content and pedagogy.

2.5 **Chapter Summary**

This chapter presented and discussed the literature reviewed related to the teacher’s conception in STEM teaching and learning. It revealed that STEM teaching and learning reform in Zimbabwe was introduced against the background of either failed or abandoned reform informing us the successful implementation of such reform might suspect. This is mainly
because it demands teachers to paradigmatically shift from current taught content and pedagogies employed in Zimbabwe to teaching of new STEM content and adopting STEM content supportive pedagogies. The chapter also discussed the integrated meta-cognition and conceptual change model that provides us with the parameters of understanding how teachers comprehend the STEM teaching and learning in this study. The next chapter discusses the methodology which was adopted for this study.
CHAPTER THREE: RESEARCH METHODOLOGY

3.0 INTRODUCTION

This chapter discusses the research methodology which was adopted in this study. It does so from the understanding of two understandings of methodology proffered in the literature. Firstly, Jacobs and Levitt (2003) define research methodology as the use of appropriate approaches and techniques to extract relevant data, which when analysed helps to draw true references from the specific phenomena. Secondly as a composite of interrelated elements grounded in a particular paradigm (Mpofu V., 2016). The methodological components discussed in this chapter are the research: (1) paradigm, (2) design, (3) context, (4) participation, (5) data generation and analysis methods, and (6) ethical considerations. The chapter concludes with a summary.

3.1 RESEARCH PARADIGM

The study adopted the qualitative paradigm. A qualitative research paradigm expresses information usually in words about views, feelings, opinions, values and attitudes (Robson, 2002). To Miler (2003) a qualitative study is:

An enquiry process of understanding a social or human problem based on building a complex, holistic picture, formed with words, reporting detailed views of informants and most importantly conducted in a natural setting.

Neuman (2011) adds that studying a problem from qualitative paradigm stand point provides the researcher with opportunities to explore and build accounts of the problem under study (Neuman, 2011).

These features of the qualitative paradigm were aligned to the study of human conceptions that involved non-quantifiable variable but quality characteristics. This meta-cognition and conceptual change integrated model provides us with the qualitative variables for investigating how teachers comprehend the STEM teaching and learning.
3.2 **RESEARCH DESIGN**

A case study design was used in the study. The adoption of this design took two factors into consideration. Firstly, the case study design is compatible with the qualitative paradigm. This design allows data to be generated in a natural setting (Comber, 2003), accommodate varied and open ideas from participants (Tuckman, 2012), and direct researchers to explore real and complex life problems (Yin, 2009). In support of this reason for adopting a case study design is its definition proffered by Lokesh (1997) that case studies are qualitative designs which allows researchers to generate data through multiple methods. Secondly, it allows the researcher to do an in-depth study of the problem with his or her defined geographical, conceptual and theoretical boundaries (Yin, 2009; Breen, 2007). This case study feature justifies my choice of studying teachers’ understanding of the STEM curriculum at Masotsha high school in Bulawayo Metropolitan province of Zimbabwe through a case study approach. However, in adopting this design the researcher was quite conscious to its major weakness highlighted by some authors. This is, that it requires the research to generate sufficient data where insufficient data can lead to inappropriate findings (Neuman, 2011). The researcher minimised this weakness through using a variety of methods to generate data with eight teachers. The use of multiple methods did not only ensure that sufficient data was collected but also addressed the issue of data authenticity through triangulation (Bowen, 2009).

3.3 **RESEARCH CONTEXT**

As alluded in the preceding paragraph, case studies are conducted in specific geographical, conceptual and methodological contexts. This study is therefore contextualised in three main ways. These are: (1) geographical location, (2) Masotsha High School STEM subjects related curriculum and (3) research participants.

3.3.1 Geographical location

This study was done at Masotsha High School in the Khami District of the Bulawayo Metropolitan Province in Zimbabwe. Masotsha High is a day School situated in an urban location in Magwegwe North of the city of Bulawayo.
3.3.2 Masotsha High School STEM related subjects curriculum

The study phenomenon context was the teachers’ conception of STEM teaching and learning at Masotsha High School. This justifies the discussion of the school’s STEM curriculum. Table 3-1 depicts the STEM related subjects the school offers and enrolments with respect to each level.

**Table 3-1:** The STEM subject related curriculum and Enrolment at Masotsha High School

<table>
<thead>
<tr>
<th>Form</th>
<th>Biology</th>
<th>Physics</th>
<th>Chemistry</th>
<th>Maths</th>
<th>Geography</th>
<th>Computer Studies</th>
<th>Agriculture</th>
<th>Combined Science</th>
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<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3-1 shows all the STEM learning areas offered at Masotsha High School. The participants for the study were taken from the STEM related subjects as their conceptions of STEM teaching and learning formed the basis for the study.

3.4 **Research Participants**

3.4.1 Population

A population is defined as a collection of all the individuals’ items or points under study (Simon, 2009). The target population of this study was all teachers teaching STEM related subjects at Masotsha High School across all levels. This population decision is justified by Baxter, Hughes and Tight (2006) who say that population includes all people with all characteristics that the researcher aims to study. The targeted population gives a population size of seventeen STEM related teachers. These consist of five (5) teachers taking physics, chemistry, biology and combined science, four (4) mathematics teachers, two (2) computer science teacher, three (3) agriculture teachers, and three (3) geography teachers.

3.4.2 Sample and sampling

Many authorities are in consensus that a sample is a part of a population under study (Tuckman, 2012). In this study the target population are the seventeen (17) STEM related subject teachers.
as discussed in section 3.4.1 above. The sample is drawn from the population. The process of drawing a sample from the target population is referred to as sampling (Miler, 2003; Singleton, 1993). The number of elements drawn from a population is known as the sample size (Mwanza, 2014). Eight purposively sampled STEM related subject teachers participated in this study. Purposive sampling seeks individuals and sites that can best supply relevant information needed to answer research questions raised (Creswell, 2007; Cohen L. a., 1994; Miles, 2001). The purposive sampling criteria used was (1) four (4) years and above of teaching experience,(2) a qualification in teaching a STEM related subject (3) currently teaching a STEM related subject, and (4) participant voluntary consent.

The voluntary consent condition was included to uphold an ethical standard in doing the research. Research ethics seek to observe and protect human rights (Dresser, 2004). The eight (8) participants signed voluntary consent forms (see appendix 1) after reading and understanding request for participation letters. The request for participation letters included all information about the research and research ethics upheld (see appendix 2).

3.4.3 Participants

The characteristics of the teachers who participated in this study are summarised in Table 3-2 below.

Table 3-3: Participants characteristics

<table>
<thead>
<tr>
<th>Participant</th>
<th>Sex</th>
<th>Teaching Experience</th>
<th>Qualification</th>
<th>STEM related subject taught</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr Dlamini</td>
<td>Male</td>
<td>4 years</td>
<td>BSc Applied Chemistry</td>
<td>Combined Science</td>
</tr>
<tr>
<td>Mr Ncube</td>
<td>Male</td>
<td>18 years</td>
<td>Diploma in Education-Science</td>
<td>Physics</td>
</tr>
<tr>
<td>Mrs Khumalo</td>
<td>Female</td>
<td>5 years</td>
<td>BSc FCS PDGE Science</td>
<td>Chemistry</td>
</tr>
<tr>
<td>Mrs Moyo</td>
<td>Female</td>
<td>8 years</td>
<td>Diploma in Education-Science</td>
<td>Biology</td>
</tr>
<tr>
<td>Mr Sibanda</td>
<td>Male</td>
<td>6 years</td>
<td>Bed in Mathematics</td>
<td>Mathematics</td>
</tr>
<tr>
<td>Mr Ndlovu</td>
<td>Male</td>
<td>8 years</td>
<td>BSc Computer Science</td>
<td>Computer Science</td>
</tr>
</tbody>
</table>
Mrs Tshuma | Female | 19 years | Diploma in Education - Geography BSc Geography | Geography
--- | --- | --- | --- | ---
Mrs. Ndebele | Female | 9 years | BSc Agriculture PDGE Science | Agriculture

Table 3-2 shows that participants in this study hold adequate teaching experience and qualifications that the researcher would count on to get relevant data to the research questions. Pseudonyms were used to preserve the confidentiality of the participants in accordance with the research ethics requirements (see appendix 2).

3.5 **DATA GENERATION**

Data generation is a process undertaken by a researcher to collect and record relevant data for analysing into findings. The process involves making decisions with regards to data sources, data generation, recording, and analysis methods as well as its nature. Table 3-3 below summarises these elements of data generation.

**Table 3-4: Research Data, Generation, Recording and Analysis Methods**

<table>
<thead>
<tr>
<th>RQ</th>
<th>Data Source</th>
<th>Data Generation</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2 &amp; 3</td>
<td>STEM subject related teachers</td>
<td>Semi-Structured Interviews (SSI)</td>
<td>Qualitative Content Analysis (QCA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SSI Guide</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recorder</td>
<td>Verbal</td>
</tr>
<tr>
<td></td>
<td>Document analysis (DA)</td>
<td>DA Guide</td>
<td>Field Notes</td>
</tr>
</tbody>
</table>

Table 3-3 shows the methods and tools used to generate, record and analyse data. It also provides the data sources and the nature of data generated. Each of these data generation aspects are discussed in turn in the ensuing sections.
3.5.1 Data Source

Data sources were used because the research is based on science teachers’ comprehension and understanding in STEM teaching and learning. The research may focus on science teachers teaching STEM related learning areas.

3.5.2 Data Generation Methods

The two methods of data generation used are discussed in the ensuing sections. These two methods were used for triangulation purposes. Triangulation is the confluence of evidence that breeds credibility (Bowen, 2009).

3.5.2.1 Semi Structured Interviews

In research, interviews are generally regarded as a data gathering method (Lokesh, 1997). They are conversations between the researcher (interviewer) and the people participating [interviewees] in the study (Neuman, 2011). There are different types of interviews that are identified by either structure or method of administrating them. On one hand, face to face, electronic and telephonic are some examples of administration methods. On the other hand structured, semi-structured and open interviews are examples of structure interviews. The use of the interview method in this study considered that they allow free response between the involved parties and also give enough space and time to speak out their mind when a conducive and comfortable environment is created (Lokesh, 1997).

This study adopted face to face semi-structured interviews. Their use recognised that semi-structured interviews are structured in a more general question way that gives the parties involved in the session a leeway to probe at the same time keeping it focused (Drever, 1995; Prakash, 2010; Mays N, 2000). This method was adopted with full awareness that it is time consuming (Hudelson, 1994) and generates massive data. However, its advantages like high response rates (Abawi, 2013), accommodation of probing (Mays N, 2000), and collection of rich data (Robson, 2002) outweighed this time consuming weakness.

Interview data were generated through an interview guide. The guide was loosely structured so that it did not provide or suggest potential responses with less than twenty items as advised by Sherraden (2001). This guide is presented in appendix 3. The semi-structured interview, however adopts a middle ground as the interviewer does not have a sequence of questions to
be asked during interview but has considerably more freedom to change the sequence, wordings and time allocated to each question based on the needs of each separate interview (Robson, 2002). The development of the interview guide was informed by research questions and the theoretical framework of the study.

In research, any tool used to generate data has to be valid (Maxwell, 1996). The descriptive validity refers to the extent of the accuracy of the data (Maxwell, 1996). Some scholars use the descriptor of credibility to capture the same concept (Maxwell, 1996; Glaser, 1967). Weber (1990) explains validity in terms of homogeneity, that is that the instrument/tool (guide) measures what it intends to measure and convergence where the instrument measures concepts in similar ways with different participants. The interview has to be trustworthy (Hennick, 2007). Trustworthy is driven by four factors, that is, credibility, transferability, dependability and conformability were identified (Hennick, 2007). Credibility implies an evaluation of whether the research findings and conclusions truly represent the conceptual interpretation of the data drawn from respondents’ original data. Patton (2002) viewed transferability as a degree to which the research findings can be applied to other situations beyond the project boundary and dependability as a means of assessing the quality of findings’ consistency. Neuman (2011) pointed out that conformability is the degree to which the research findings are supported by the data collected, that is, the extent to which the findings are shaped by the respondents and not researcher biased.

The validity of the interview guide was ensured in three main ways: (1) its development was informed by the RQs and aspects of the theoretical framework, (2) reviewed by peer researchers (3) supervisor reviewed and (4) document analysis data. Weber (1990) mentioned that document analysis provides preliminary study for interview or observations and this helped the researcher to formulate some interview questions.

### 3.5.2.2 Document Analysis

Document analysis is a qualitative research method where documents are interpreted by the researcher to give voice and meaning around an assessment topic (Bowen, 2009). It [document analysis] is a non-reactive and unobtrusive method of data gathering method that gives the researcher a high volume of data pertaining the participants (Leedy, 1997). Further, document analysis is an invaluable part of most schemes of triangulation, the combination of methodologies in the study of the same phenomenon (Bowen, 2009).
The document analysis method was adopted because documents can reveal something about perceptions, views and values of the individual who constructed the text (Chism, 1999). Of the three primary types of documents: Public records, personal documents, and professional documents (O’Leary, 2014), the professional documents were analysed. The professional documents analysed were the new curriculum and teacher generated documents.

Document analysis data was informed by the self-developed DA guide as presented in appendix 4. Like the SSI guide, the development of the DA guide was informed by research questions and the theoretical framework of the study. Its validation went through peer and supervisor reviews.

3.5.3 Nature of Data

As shown in Table 3-3 above verbal or conversation data was generated from semi structured interview and written or text data was generated from the analysis of documents. Both conversation and text data are qualitative in nature. Qualitative data include transcripts of individual interviews, field notes, and copies of documents, audio recordings from observation of certain activities obtained from concepts, opinions, values and behaviours of people in a social context (Patton, 2001). In qualitative data analysis, in order to understand a complex phenomenon you must consider the multiple realities experienced by the participants themselves, that is, the insider perspectives.


3.6 **DATA GENERATION PROCEDURE**

The data presented in section 3.5.3 above was generated in four steps as shown in Figure 3-1 below.

![Figure 3-1: Data Generation itinerary](image)

**Figure 3-2: Data Generation itinerary**

Data was generated in four main steps as shown in figure 3-1 above. Table 3-4 below is showing how these stages were implemented.

**Table 3-5: Field Itinerary**

<table>
<thead>
<tr>
<th>DATE(S)</th>
<th>ACTIVITY</th>
<th>Session evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>31-03-18 to 01-04-18</td>
<td>Researcher Analysis of the new curriculum document</td>
<td>All the new curriculum documents were analysed and compared with the old curriculum documents. New curriculum documents analysed included the Agriculture, geography, mathematics, biology, physics, chemistry, combined science and computer science syllabi. Topics have been expanded and cross-cutting themes identified. Agriculture syllabus not clearly printed.</td>
</tr>
<tr>
<td>02-04-18 to 04-04-18</td>
<td>Researcher – participant interviews documents SSI</td>
<td>The researcher moved around house to house, to school, holding first interview sessions. Smartphones were used to record the interview sessions. This was done after pre-analysis of the teacher generated documents. The process was cumbersome since it was</td>
</tr>
</tbody>
</table>

36
done during school holidays and participants were spread all over Bulawayo. However, interviews were carried out using all the possible time in the morning and afternoon at various locations. Time and location for the next interview sessions were negotiated for after the first interview taking into consideration the availability patterns of the participants. An average number of 2-3 teachers were interviewed per day.

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>05-04-18 to 06-04-18</td>
<td>Analysis of teacher generated documents School documents that were at school, that is, the schemes of work were analysed at school as the researcher was given up to Friday by the school head so that the teacher generated documents would be available to the STEM related subject teachers for vacation school lessons that were starting the following Monday (09-04-2018). The second interview session with the Chemistry teacher was done on the 6th of April as her schedule was not open during the pre-planned dates as she wanted to travel to her rural home.</td>
</tr>
<tr>
<td>07-04-18 to 09-04-18</td>
<td>Researcher – participant interviews documents SSI After the analysis of the teacher generated documents a second session of interviews was conducted. A similar situation prevailed were the researcher moved from house to house, to school depending on the availability of the participants. Afternoon and morning times were used. Smartphones were used for recording during the interview sessions. Consent forms were signed for the second interview sessions. A recording of the first interview session was played again to the participant on request to give context to the interview.</td>
</tr>
</tbody>
</table>

All the activities carried out during data gathering were authorised. Research authority for access to participants was sought in line with ethical considerations in doing the research. To
uphold these ethical standards, the researcher sought and obtained authority from various levels of the Ministry of Primary and Secondary Education (MoPSE). These were at Provincial and District Education Offices, school and STEM related subject departments.

A letter of introduction was obtained by the researcher from Bindura University of Science Education (BUSE) (see Appendix 5). The letter of introduction was attached to application letters that sought permission to conduct this research. The profoma application letter is shown in Appendix 2. The province of Bulawayo and Khami District and Masotsha High school granted me authority as shown in appendices 6 and 7 respectively.

3.7 Qualitative Content Analysis (QCA)

Table 3.2 shows that qualitative content analysis was adopted to process data into findings or information. Data is defined by Miles and Huberman (2001) as a representation of facts, concepts or instructions in a formalised manner suitable for communication, interpretation, or processing by humans or by automatic means. Webber (1990) defines information as data that is organized and meaningful to the person receiving it. Information has a meaning in that it comes from selecting data, summarizing it and presenting it in such a way that it is useful to the recipient (Creswell, 2007). Data is therefore raw material that is transformed into information by data processing. Information brings in the surprise value by telling the researcher something he did not know. In other words it gives meaning to data.

Qualitative content analysis is the procedure for the categorization of text, verbal or behavioural data for the purpose of classification, summarization and tabulation (Miles, 2001). Content analysis can be done on two levels, that is, descriptive and interpretative. In descriptive terms it asks the question, ‘What is the data?’ and in interpretative it asks the question, ‘What was meant by the data?’ The QCA approach was done through eight (8) main phases as discussed below.

Phase 1 Preparation of data

The gathering of data through interviews and document analysis. Field notes were developed document analysis. Audio recording was used for the SSI process and eight written transcripts were developed from the first interview session and another eight [transcripts] from the second interview session.
Phase 2

Defining the unit of analysis, that is, messages have to be unitized before they are coded and placed into themes.

Phase 3

Develop categories and a coding scheme. This involves three sources, that is, the data, previous related studies, and theories.

Phase 4

Testing the coding scheme on a sample of text.

Phase 5

Coding all the text,

Phase 6

Assessing the coding consistencies.

Phase 7

Drawing conclusions from the coded data. This phase involves making sense of the themes or categories identified, and their properties. At this phase, the researcher will make inferences and present the reconstructions of meanings derived from the data. Your activities may involve exploring the properties and dimensions of categories, identifying relationships between categories, uncovering patterns, and testing categories against the full range of data (Bradley, 1993).

Phase 8

Methods and findings. For the study to be replicable, there is a need to monitor and report analytical procedures and processes as completely and truthfully as possible (Patton, 2001).
3.8 **Data Presentation**

Lokesh (1997) described data analysis procedures as strategies employed to break down raw data into meaningful information. The research used the qualitative approach in the collection of data. The data were categorised into themes. A theme was defined by Howitt and Crammer (2008) as a cluster of linked categories conveying similar meanings. Data were coded into themes from interviews and document analysis. The meaning of STEM was categorised into themes such as STEM related subjects and STEM as an acronym. Data from the relationship of STEM to STEM teaching and learning were divided into themes such as, integrated teaching and learning of STEM and application of STEM related principles. Eight themes were developed from the teachers’ interpretation of the new curriculum demands and these are, content, pedagogy, teacher role, learner role, teacher-teacher collaboration, teacher-community collaboration, assessment and ICT integration. Descriptive narrative form and verbatim quotations were used to discuss the findings with a few quotations from literature review. A claim was made, followed by evidence, then literature and finally a discussion.

3.9 **Chapter Summary**

Chapter three discussed the qualitative approach were the case study design was adopted. This helped the researcher to use self-designed semi-structured interview guides and document analysis guides. A sample of eight participants was purposively chosen from a population of seventeen participants at Masotsha High School in Bulawayo Metropolitan Province. Discussions on sampling and data analysis procedures were done. The next chapter will look at data presentation, analysis and discussion of the results.
CHAPTER FOUR: PRESENTATION AND DISCUSSION OF FINDINGS

4.0 INTRODUCTION

This chapter presents and discusses findings relating to science teachers’ conceptions of STEM teaching and learning at Masotsha High School. This study sought to answer three questions which are (RQ 1) What does STEM mean to the science teachers at Masotsha High School? (RQ 2) How do these teachers comprehend STEM Education in relation to STEM? (RQ 3) How do these science teachers interpret the new STEM curriculum? The answers to these questions form the organisation of the chapter. These are (1) Teachers understanding of STEM, (2) Relationship of STEM to STEM education, and (3) Teachers’ interpretation of the new STEM curriculum. The chapter summary closes this chapter.

4.1 TEACHER’S UNDERSTANDING OF STEM

Eight (8) science teachers who participated in this study held two main meanings of STEM: (1) STEM as an acronym and (2) STEM as a group of STEM related subjects.

4.1.1 STEM as an acronym

Four (4) of the participants viewed STEM as an acronym. This means that STEM is seen as a word formed from the initial letters of the several words in the name and pronounced as one word. For example, Mr Sibanda in the following excerpt defined this construct as:

STEM is an acronym for science, technology, engineering and mathematics.

Mrs Khumalo and Mrs Ndebele held similar views and said:

STEM is science, technology, engineering and mathematics… (Khumalo)

STEM is an abbreviation that stands for science, technology, engineering and mathematics (Ndebele).
While Mr Ncube concurred with the above definition of STEM, he added that:

It’s [STEM] a concept that brings science, engineering, technology and mathematics together.

This view of STEM lands support of diverse literature. For instance, Angier (2010) and Zollman (2012), simply defined STEM as standing for science, technology, engineering and mathematics. The new STEM curriculum in Zimbabwe also defined STEM as standing for science, technology, engineering and mathematics (Gandawa, 2016). These teachers’ view of STEM can be attributed to media promotion of the STEM curriculum upon its introduction. For example, the economic slogans: “STEMITISATION for addressing social and national economic challenges” and “IF WE STEMITISE, WE INDUSTRIALISE” which was written on the roadside billboards of the Harare Polytechnic and the Zimbabwe Manpower Development Fund (ZIMDEF) respectively (Mberi, 2016). These testify to the assertion that media promotion have an effect on peoples’ views. Since then STEM has become a buzz word in Zimbabwe. Unfortunately STEM means more than just an abbreviation as some scholars like (Morrison, 2006) posits that STEM is the interdisciplinarity of STEM related disciplines into an entity. This implies that traditional and separatist approaches to science, engineering, technology and mathematics disciplines are dismantled and these disciplines get integrated.

This view of STEM as an acronym insights us that some science teachers hold a surface understanding of STEM. The traditional and separatist approach of teaching STEM related subjects has been found to be failing students in performing well in STEM related carriers. This is retrogressive to the goals of the new STEM curriculum in Zimbabwe to recuperate the ailing economy and placing the nation as one of the leading nations in invention and innovation.

4.1.2 STEM as STEM related subject

Four (4) of the participants defined STEM as STEM related subjects. This means that STEM is viewed as the science subjects offered at secondary school level such as biology, chemistry, physics, mathematics, geography etc. For example, Mr Dlamini in the following excerpt defined STEM as:

…a subject [Combined Science] that consists of STEM related subjects, that is, physics, chemistry and biology that are taught in combined science.
This view was supported by a variety of participants. Ms Moyo’s and Mr Ndlovu’s had similar opinions and revealed:

STEM develops skills in Biology as a science subject (Moyo).

In computer science as a science subject that falls under the technology part of STEM and develops skills and concepts in computer science (Ndlovu).

The study gives insights that most science teachers might be holding a surface understanding of STEM as the teaching of STEM related subjects such as Computer Science, Biology, and Combined Science only etc. Such teachers might be drawing this meaning of the STEM curriculum from the Zimbabwean new curriculum framework and some scholar who list the STEM related subjects in our school system as Additional Mathematics, Physics, Chemistry, Biology, ICT, Agriculture, Geography and Physical Education, however these are the transitional subjects to STEM related carriers (MoPSE, 2015; Parawira, 2016). This perspective of STEM simply lists the STEM related subjects taught at secondary school level. It is merely emphasizing of the teaching and learning of STEM related subjects. However, STEM has a deeper meaning to it than simply teaching STEM related subjects. This is attested to by Hom (2014) who defined STEM as a curriculum based on the idea of educating students in four specific disciplines, that is, science, technology, engineering and mathematics in an interdisciplinary and applied approaches.

Therefore, STEM is the application of science concepts in an integrated approach. Hom (2014), continues and lands more support to this view by further stating that STEM integrates STEM related subjects into a cohesive learning paradigm based on real-world applications. This is a shift from the disciplined and separatist approach of teaching STEM related subjects in that it demands the teachers integrates concepts from other STEM related subjects into their teaching of the science subjects as well as relate to real-world applications. The four subjects are taught as a single entity rather than teaching them as discrete or separate entities and the concepts are applied in the real-world.

Such views of STEM as a list of STEM related subject is still limited as it promotes subject specificity and based teaching and learning as opposed to the desired integration of content and concepts. The ultimate objective of the new STEM curriculum is to position Zimbabwe as a global leader in scientific discoveries and technological breakthroughs by incorporating diverse
concepts from different scientific disciplines and apply them to real life problems and possible solutions. But with this separatist and traditional view of STEM I am afraid this goal will remain a pipe dream.

4.2 RELATIONSHIP OF STEM TO STEM TEACHING AND LEARNING

The eight (8) participants linked STEM teaching and learning to STEM in two ways: integrated teaching and learning of STEM related subjects and the application of STEM related principles.

4.2.1 Integrated teaching and learning of STEM related subjects

Three (3) of the participants linked STEM teaching and learning to STEM in pedagogical terms as the integrated teaching and learning of STEM related subjects. Integrated approach means the concepts and content is merged or not separated within subject’s lessons like chemistry and mathematics. An excerpt extracted from the data generated with Mrs Dlamini, related STEM to STEM teaching and learning as the:

…development of knowledge, understanding and practical skills of basic scientific concepts and principles as well as to handle information and critical thinking by integrating biology, chemistry and physics to form combined science.

This was supported by the computer science teacher generated document that defined STEM teaching and learning in relation to STEM as:

…the integration of computer skills and using these skills in other STEM related subjects such as physics, chemistry, biology and mathematics (Ndlovu).

Mr Ncube added:

It [STEM to STEM teaching and learning] integrates physics concepts and these are used in other STEM related subjects.

Most literature say STEM teaching and learning relates to an interdisciplinary learning approach, 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 (Tsupsos, 2009). Such pedagogical approach develops in student STEM literacy that build in them the ability to compete in the new economy. The ultimate goal of STEM education is to produce a student
who can adapt in any situation and become a productive member of the global community. The new curriculum framework document states that STEM education empowers learners with the most important skills that they need in order to be productive citizens (MoPSE, 2015). Chitate (2016) further adds to this point by stating that STEM education reform posits that the ZimAsset’s mission is to provide an enabling environment for sustainable economic empowerment and social transformation for the people of Zimbabwe. The integration of STEM related subjects will help develop the relevant skills needed to resuscitate the ailing Zimbabwe economy and industries.

This pedagogical view of STEM teaching and learning does not bring out the clear relation of STEM with classroom practices. It should be borne in mind that STEM is grounded in the scientific discipline whose focus is on knowledge production. STEM teaching and learning hence draws content from the scientific and technology developed into an educational curriculum. This lends support of Lawton (1983) who argues that a curriculum is a selection from culture. Wherein, the world of scientific knowledge and technology is a cultural practice (Aikenhead, 2001). Classroom practices then translates how scientist and technologist develop their innovation to classroom practices (Kaufman, 2003). The link, therefore, is not only on the integrated and application of STEM subjects and concepts to real-world problems (Tsupros, 2009).

The findings revealed that the science teachers could not relate STEM to STEM education as their view was still disciplined in the separatist ideology. A worrisome trend is that science teachers do not appreciate the integration of STEM related subjects which is a paradigm shift from the disciplined and separatist approach of teaching and learning STEM related subjects in that it requires that the teachers integrate concepts and content into their teaching as well as relate to the immediate environment. Therefore, it can be concluded from this perception that, the implementation of the STEM program can only be successful when the whole education fraternity views the integrated nature of STEM education as key.

4.2.2 Application of STEM related principles

Five (5) of the participants linked STEM to STEM teaching and learning as the application of STEM related principles. Application of STEM related principles involves the action of putting concepts into action. The geography new curriculum document:
…equips learners with skills to understand location, patterns and processes of phenomena and apply these in other subjects … (Tshuma).

Mr Sibanda’s documented stated that:

STEM to STEM teaching and learning involves the application of mathematics in other STEM related learning areas. Competencies in mathematics such as critical thinking and problem solving are used to develop an appreciation in the role mathematics plays in personal life, community and national development.

The same perspective were held by the majority of participants during the interview sessions and they said:

Skills acquired in agriculture can be used in other STEM related subjects like geography, biology or even commercials and humanities … (Ndebele).

Biological scientific methods can be applied in other disciplines … (Moyo).

Learners acquire research, experimental, enterprising and technological skills in Chemistry and apply this knowledge in other STEM related subjects. For example the concept of nuclear physics is used in chemistry in the teaching of isotopes (Khumalo).

The participants linked STEM and STEM teaching and learning in terms of application of concepts and skills from one STEM related learning area to another. The separatist approach in the teaching and learning of STEM related subjects was still part and parcel of their mindset. Most literature contrasted with this view and propose the relationship between STEM and STEM education includes that the later bridges knowledge, skills and beliefs into an intersection from the separate disciplines (Corl, 2014). STEM education, hence STEM teaching and learning is a paradigm shift that emphasizes teaching Science, Technology, Engineering and Mathematics in an integrated and interdisciplinary applied approach (Parawira, 2016). Traditionally, the STEM subjects mentioned above were largely taught separately. In contrast the new curriculum framework emphasizes on an integrated teaching approach that underscores the interrelationship of science, technology, engineering and mathematics (MoPSE, 2015). It integrates them into a cohesive learning paradigm based on real world applications. STEM education emphasizes student exploration and problem solving instead of rote learning where students are exposed to memorizing and repetition and routine learning (Parawira, 2016).
The ultimate goal of STEM education is to integrate concepts and subjects in STEM related courses and produce an adaptable human being.

The findings revealed that the science teachers’ link of STEM to STEM education was still based on the traditional view of the STEM related subjects as individual subjects. The STEM related subjects are still taught as separate entities in the comforts of their traditions in the new curriculum. The science teachers' views on STEM and STEM education is very important as it can be transferred to the learner who is being counted on to resuscitate the ailing Zimbabwean economy. It can be concluded from the findings that most science teachers have a separatist view of the teaching and learning of the STEM related subjects.

4.3 Teachers’ Interpretation of the New STEM Curriculum

The new STEM curriculum is a ‘new old curriculum’ which emerged in eight (8) themes. Teachers’ interpretation of the STEM curriculum emerged in [eight themes]: (1) Content demands, (2) Pedagogical demands, (3) Teacher role shifts, (4) Learner role shifts, (5) Teacher-teacher collaboration demands, (6) Teacher-community collaboration demands, (7) New assessment approaches demands and (8) ICT tools integration demands.

4.3.1 Content demands

The study revealed that the STEM curriculum has no new content but rather has expanded the traditional content in terms of both breadth and depth. Content is the subject matter knowledge. Eight (8) participants shared the view that the new curriculum merely expanded the traditional content in terms of both breadth and depth. The following excerpts from four (4) of the participants capture this notion:

… in combined science certain topics where expanded, for example a sub-topic under health and disease (Combined Science Syllabus, Section 8.7.11, p.47) has been expanded to include diseases such as Ebola and typhoid that are now taught together with cholera, malaria and bilharzia … the content is delivered in a similar manner, looking at signs, symptoms, cause, treatment and prevention of the diseases (Dlamini).

In chemistry the teacher is currently teaching a topic on soap manufacture. This is a sub-topic under organic chemistry, meaning that this topic has been simply expanded to include the new sub-topic (Khumalo).
This was also revealed during the interview sessions where the science teachers pointed out by stating that:

Most topics in geography have been retained and some were just concepts in the old curriculum, but now they are major topics in the curriculum, for example, geographical information systems (GIS). The use of indigenous knowledge systems (IKS) in the ecosystem has been expanded where cultural beliefs are applied in the conservation of animals and plants … for example in Ndebele culture certain tree logs are used to cover a grave after burial, trees such as “umphafa” and “umsehla” in Ndebele. This helps in the conservation of these trees (Tshuma).

The new curriculum has retained quiet a number of topics. There is more of the practical aspect such as web designing, data base design and programming (Ndlovu).

However, this has brought another aspect, pointed out by Mrs Khumalo who further said:

The depth of the syllabus has increased, examples have to do with the environment. There is now a need for upgrading as a teacher academically.

These findings reveal that the STEM curriculum is the “new old curriculum” which has merely added content of the respective curriculum. In support of this finding is the statement in the new curriculum framework document that says:

A learning Area is a cluster of knowledge domains around which related themes and topics are constructed. Therefore, learning areas constitute the content of the curriculum. Additionally, learning areas reflect cross-cutting themes which contribute towards the achievement of desired learning outcomes. Furthermore, learning areas define learning outcomes and provide breadth, depth and balance in learners’ education (MoPSE, 2015).

These cross-cutting themes in STEM related subjects are ICT, IKS, HIV/AIDS, environmental issue etc... (MoPSE, 2015). Content Knowledge in these additional topics in STEM related subjects will give the teacher confidence, and this confidence is transferred to the learner. A teacher with good content knowledge has an easier task of relating this knowledge with Indigenous Knowledge and Nature of Science, hence improving STEM specific Pedagogical Content Knowledge. Pedagogical Content Knowledge (PCK) is the knowledge needed to make subject matter accessible to students (Ball, 2008). However, strong Content Knowledge does
not necessarily lead to the development of Pedagogical Content Knowledge (Lee, 2007). As reflected by the qualifications of the participants in this study (see Table 3-2), STEM teaching and learning requires STEM content which is not provided in the curriculum. The implication is that teachers having been trained within areas of specialization hold content that does not support the stemitization of their subject in the classrooms.

These findings are aligned to the teachers’ views of STEM education as the teaching and learning of STEM related subjects. As a policy the STEM curriculum seems to lack clear direction of what STEM content to teach. This finding concurs with Moyo and Ramirez’s (2017) view that for now, the STEM curriculum is mere policy that does not provide clear guidelines on classroom practices. STEM teaching and learning has therefore been merely popularized through slogans similar to those chanted in political rallies. These slogan have not been unpacked in terms of what content to teach. Though in some STEM related subjects like geography content has been increased to incorporate indigenous knowledge (IK) aspects. The problem is that the aspects of IK that forms classroom content has been left to the teachers. These teachers have be trained to teach only western science subject specific content and would be limited of what IK content to teach and how to teach it.

4.3.2 Pedagogical demands

Data from the eight (8) participants revealed that pedagogical approaches to the STEM curriculum based subjects remained the same as with the old curriculum. Pedagogy is not only the activity of educating (Baumert, 2010) but also a philosophy about how teaching and learning takes place (Siraj-Blatchford, 2002). Some of the excerpts evidencing that data from which this finding was drawn are presented below:

…cross-cutting skills … include experimentation, discovery, demonstrations, problem solving, critical thinking, project based learning, simulations and many more… (Moyo)

Some participants summarised their activities after lesson delivery as:

I give my students homework to prepare for a discussion and presentation (Tshuma).

In the classroom some participants revealed that they were still using traditional approaches to teaching their specific subjects as captured in the excerpts below:
Currently, I am teaching functional graphs … use the metre ruler, white board and markers to teach this topic (Sibanda).

I am teaching soil and water and basically we engage in discussions (Ndebele)

Ncube said:

….at the moment I am teaching kinematics and forces. I am using practical lessons to harness problem solving skills. Basically [this] is a learner centred, research based and investigative approach…

The findings are evidencing that these STEM related subjects are drawing pedagogical approaches from the new curriculum which area no difference from those of the previous curriculum. This finding disagrees with scholars who affirm that a new STEM pedagogy must shift from teacher-centred to student-centred approaches. Student centred approaches include inquiry-based, problem-solving, discovery and design based learning (Joyce, 2011). The new curriculum framework document on STEM states that it seeks to use the learner centred approach through inquiry based teaching, using the discovery, project based learning, problem solving and design based learning methods in order to harness STEM skills in learners (MoPSE, 2015). Further, it states that STEM teaching and learning seeks to cultivate critical thinking, problem solving, logical analytical competency, numeracy, inclusivity, technology and innovation amongst many skills (MoPSE, Combined Science Syllabus (2015-2022), 2015). All this aims at developing 21st century knowledge and skills in students that they need to advance economies through active participation in science and technology. The 21st century knowledge and skills agenda demands an educational institution product who is capacitated to apply knowledge and skills gained in one discipline to another, what they learn in school to other areas of their lives within and outside the school (Moyo P. &., 2017). But, in stemitising the teaching of specific subjects a STEM integrated pedagogy is called for (Mpofu & Vhurumuku, 2017). Theoretically, STEM integrated pedagogical approaches use the traditional learner centred approaches as ingredients. These ingredients are mixed in a way that support the STEM content.

Regrettably, the new STEM curriculum has not defined its content. In consequent, the teachers are interpreting the pedagogical demands using the old or traditional lenses. This might not be their fault given traditional grounding training that provides teachers with pedagogical
knowledge and skills which are non-supportive to STEM teaching and learning (Mpofu & Vhurumuku, 2017).

4.3.3 Teacher Role Shifts

Data revealed that the teachers who participated in this study defined their teaching roles in the traditional sense. That is, they are still mired in the traditional roles of teacher to student transmission of knowledge which is of little significance in STEM teaching and learning. A role is an activity assigned to an individual (Viera, 2008). Traditionally, the role of a teacher is to be the sole source of information and knowledge (Cohen L. M., 2004). Numerous extracts from the data generated with participant’s evidence the teachers’ traditional roles in stemitising their subject teaching as presented below:

After lesson delivery, I engage in research since most of the content covered is not in the old textbooks (Tshuma).

Mr Dlamini said:

After lesson delivery, I research and plan for the next lesson and mark work from the learners.

Other participants also added:

During a lesson we hold a class discussion and points they have researched on are brought forward (Ndebele).

During a lesson on functional graphs, I use the metre rule, white board and marker to teach the concept (Ncube).

In the teaching of Ecosystems I use class discussions, presentations, chalk and board methods… (Moyo).

Adoption of traditional roles in stemitising subject teaching and learning contradicts the teacher as facilitators and learners roles advocated for by scholarship in STEM curriculum. The reformation of the instruction of subjects across STEM fields changes the role of STEM educators from being classroom or laboratory “dictators” to being facilitators of students’ activities (Ejiwale, 2013). The teacher acts as a co-explorer and facilitator in knowledge discovery in order to arrive at an objective understanding of content and demonstration of skills
so acquired (MoPSE, 2015). This can be attributed to his willingness to adapt to change and experience. MoPSE (2015) further states that the role of the teacher is to use a wide range of methods adapted to the learner’s situation and needs in the context of interactive pedagogies and reinforce connections between learning areas and disciplines and promote STEM integrated learning. It is argued that the assumption of facilitation and learning roles by teachers creates classroom enterprise environments that support teacher-students active participation and knowledge sharing. This, in turn enhances solving problems, self-reliant and harnesses independent thinker’s skills in both teachers and students.

The teachers’ retention of traditional teaching roles is a threat to the successful implementation of the STEM curriculum. This has consequences that it fails the endeavours of science education as the cornerstone of the economy through laying a strong foundation for science and technology. The need to capacitate the teachers for these new roles cannot be over emphasized.

4.3.4 Learner Role Shifts

Data generated with the eight (8) participants evidence that these teachers hold the traditional notions that the student roles in classroom enterprises remain learning. Exemplary excerpts from which this finding emerged are provided below.

At the moment I am teaching ecosystems using the board and chalk method. Class experiments are carried out where necessary, but as a class due to shortage of chemicals. The concept of practical based teaching in order to arrive to theoretical concepts is needed … from concrete to abstract … however lack of resources such as chemicals hinders this (Moyo).

White boards and markers are mostly used due to the fact that there are few working computers (Ndlovu).

Practical experiments are done as a single unit where the teacher conducts the experiment in front of the learners (demonstrations) (Khumalo).

As shown by these teachers adopted pedagogy (see sections 4.3.2 and 4.3.3), teachers’ roles have not shifted meaning learner roles have also not shifted. These teachers seem to be deliberately ignoring that provision of the new curriculum that “The roles of the learner have been laid out in the new STEM curriculum as the creation of a learner who is aware of learning
objectives and expected learning outcomes (learner competency), participates in the construction of learning experiences and has a choice and participates in inquiry and problem solving learning, as well as in collaborative and community service oriented learning (MoPSE, 2015). The learners role is central in STEM education in order to produce an individual who is a critical thinker and able to solve the perennial problems facing the country.

The new STEM curriculum is advocating for pedagogy that is STEM integrated (Mpofu & Vhurumuku, 2017). The curriculum framework stresses learner-centred approaches, the focus on learning revolves around learners as they engage in the search and discovery of new knowledge (MoPSE, 2015). Meaning that learners can adopt teaching roles as well and learning becomes their sole responsibility.

This finding is insightful that the majority of science teachers are not aware that STEM teaching and learning as purported by Mpofu and Vhurumuku (2017) demands a shift from the traditional and separatist pedagogies to that of STEM integration. Without this shift in mindset, STEM concepts are not always easy to grasp particularly when dealing with dynamic and complex concepts that cannot be easily explained and illustrated in a textbook (Joyce, 2011). The reasons for an unwillingness to shift learner roles could be due to resistance to curriculum change which due to limited content and pedagogy to implement the new STEM curriculum and negative attitudes towards the new curriculum reform (Chere, 2015).

4.3.5 Teacher-Community Collaboration Demands

Data revealed mixed interpretation of the new STEM curriculum’s teacher-community collaboration demands. Four (4) of these participants showed an awareness of the need for teacher-community collaboration. Collaboration is the act of working jointly with other stakeholders in science education. Participants said:

A chicken fowl run trip to uMguza area has been planned. Learners will visit Rick-saw farm (commercial farm) and resettled farmers so that they can compare and gain the world applications of farming (Tshuma).

A field trip to a computer organisation has been planned where computer science students can experience the real world scenarios that are based on computer implementation of data bases in their day to day activities, however funds have not been permitting (Ndlovu).
Currently I am teaching soap making in organic chemistry. I am arranging an educational tour to visit Nkulumane [Bulawayo Complex] industries with the learners so that they can observe soap making in real world situations (Khumalo).

The new curriculum framework stipulates that teaching and learning needs to engage learners with issues of addressing real-life problems within the context of networked learning and transform schools from mere buildings to nerve centre spaces that connect teachers, learners and the surrounding community in an integrated and interdisciplinary learning environment (MoPSE, 2015). MoPSE (2015) further adds stakeholders, namely: the parents, communities and captains of industry and commerce are expected to play an active role in the implementation of the new STEM curriculum to ensure that learners achieve the desired outcomes. Unfortunately, in terms of teacher-community collaboration, these teachers have interpreted this to mean engaging students in educational tours. Yes, educational tours links schools and student to communities and organisations where scientific principles are applied but do not necessarily mean that. But, teacher-community collaborations are deeper than that. They entail that all sectors of the community (teachers, industrial and commercial experts, parents, and others) engage in planning and teaching of STEM related subjects to build consented education systems in the communities where schools are located. Teams consisting of community-based STEM educators and industries or educational institutions can co-develop and co-teach a collaborative curriculum focused on community needs (NSTA, 2003). When teachers and community institutions (eg. Local businesses, community colleges and health institutions) collectively agree on their goals and decides how to reach them everyone benefits (Shaeffer, 1991). Such collaboration efforts have been seen in the Bulawayo province. For example, at district levels educators in the STEM related subjects were organised to teach science students at O and A levels during the weekends under a program managed by the National University of Science and Technology Schools Education Program (NUSTSEP). Another team was organised under the umbrella of Lupane State University Schools Education Program (LUSEP) focusing mainly on geography. It is unfortunate that these teachers have not realised this type of collaboration.

Of concern, is the lack of data with the other four (4) teacher participants who did not mention any awareness of teacher-communtiy collaboration demands of the new curriculum framework.
These findings have implications in that science teachers limit their understanding of teacher-community collaboration to educational tours only, whereas, the concept is broader encompassing various sectors of the educational, industrial and local community sectors. The consequence is that the students are not linked with the whole package of the community, which includes industry, commerce, educational, health, security and other sectors found in their community. This hinders the exchange of ideas between the student and the whole community. In the process [of teacher-community collaboration] the student gains real-world experience and can come up with local based solutions. In teacher-community collaboration, the student, teacher, school and community (industry, health, commerce etc.) benefit through improved understanding of the problems affecting all the parties (Sessa, 2006) Lack of teacher-community collaboration removes the ability of the STEM student to identify the real problems facing their community and the student will not be able to apply his knowledge and skills learned in class in real world situations.

4.3.6 Teacher-Teacher Collaboration Demands

Data generated with the eight (8) participants evidence that these teachers hold mixed interpretations about the teacher-teacher collaboration demands of the new STEM curriculum. The new curriculum demands stakeholder collaboration in stemitising the teaching and learning of STEM related subjects. Teacher-teacher collaborations are a form of intra-ministry of education stakeholder collaborations. For instance, data generated with two (2) participants depict their awareness of this demand. Some excerpts drawn from this data captures this finding:

A lot of research is needed, ‘whatsapp’ groups between teachers are there where information on how to scheme, tackling challenging topics, question papers from other countries where combined science has already been implemented can be shared (Dlamini).

Resource persons and social networks for discussions have been used. Resource persons within and outside the school have been used, for example, when covering statistics and geographical information systems (GIS), mathematics and computer science teachers where used in tackling these topics (Tshuma).
These participants stressed the importance of the use of social media and resource persons in sharing and integrating knowledge and concepts among STEM related teachers and their views are in tandem with the ideals of the new STEM curriculum.

Of concern, six (6) participants whose data reveal that they are not aware of the teacher-teacher collaboration demands. Two (2) excerpts from these participants are as follows:

There are some topics that I find difficult to teach such as genetics and breeding in Forms 3 and 4 agriculture. However, I research even though the information I get is not enough (Ndebele).

Logic gates are a difficult concept, however, if the school could permit me to use the services of the physics teacher in teaching this concept, students may understand better this concept… (Ndlovu).

The teachers are unaware that they can use the services of their colleagues in the teaching of genetics in agriculture, the biology teacher could be asked to teach the students and the teaching of logic gates, the services of the physics teacher could also be employed.

Some scholars argue that, STEM teaching and learning at school level settings must foster interdisciplinary knowledge and skills that are relevant to life and prepare students for a knowledge-based economy (NRC, 2011). Not all teachers are effective in all the topics in a curriculum, a fresh mind set is needed in order to bring in new ideas in the STEM teaching and learning process. The main goal of STEM teaching and learning is to raise the current generation with innovative mindsets, that is, the ability to think outside the box in order to solve current complex problems and emerge with lasting solutions. STEM education that is integrated offers students one of the best opportunities to experience learning in a real world situation, rather than to learn bits and pieces and then to have to assimilate them at a later time (Tsupsos, 2009). A perspective from another science teacher will help in integrating STEM concepts.

The findings reveal that the majority of the science teachers are not using the services of other STEM related teachers in assisting them in the teaching of topics and concepts that they are weak in. Use of resource persons from either within or outside the school can help in the sharing of knowledge and skills and in the process bring in STEM integration. The consequence is that students are not given the opportunity to see the link between the STEM related subjects. A
resource person from another STEM related subject can help interlink the content and concepts of STEM related subjects and in the process the student gains collaborative skills.

4.3.7 New Assessment Approaches Demands

All (eight) participants expressed an awareness to the new STEM curriculum assessment demands. Assessment is the act of judging or placing a value on an object (Andrade, 2009). Mr Ncube contributed and said:

Students are being profiled based on the external and internal exams, where the difference is that the coursework (formative assessment) is now part of the final mark combined with summative assessment mark.

Mr Dlamini added:

…in combined science like other subjects such as physics, chemistry and biology there is now a paper 3 practical paper which is now compulsory.

Excerpts from the various new syllabi revealed the following:

Continuous assessment in chemistry is 40% and 60% summative assessment of the total mark (Khumalo).

In agriculture, continuous assessment is 30% and 70% summative assessment of the total mark (Ndebele).

In computer science, continuous assessment is 20% and 80% summative assessment of the total mark (Ndlovu).

Mr Sibanda added:

Tasks and projects form part of the continuous assessment (formative assessment) and are set and marked according to Zimsec guidelines.

The study revealed that all the participants (8) were aware that STEM teaching and learning demands new learning progress assessment approaches irrespective of their academic or professional disposition. The new curriculum framework states that everyone along the chain of the teaching process is involved in assessment, the learner carries out assessment tasks and projects and does self-assessment, the science teacher grades the tasks and projects, and the
school head monitors continuous assessment and learner profiles (MoPSE, 2015). It is noted that the difference between the old curriculum and the new curriculum in terms of assessment is the bringing in of the formative assessment mark into the final mark of the total grade.

Andrade (2009), posits that STEM assessment methods that could be adopted include assessing the learning that occurs during the task and project formation processes and considers the real-world skills of problem solving, critical thinking, communication and collaboration. Projects and tasks require that students apply skills and knowledge learned in the classroom throughout the task and project formation processes. This will present the teacher with the opportunity to manage the tasks and projects progress. However, the new STEM curriculum does not provide guidelines on the training of STEM related teachers in the marking standards of formative assessment expected by ZIMSEC so as to bring uniformity, credibility, validity and reliability to the system.

The findings revealed that the STEM related subject teachers were aware of the new curriculum demands in terms of assessment. However, have not been trained in the marking of continuous assessment tasks and projects. This new assessment model has been necessitated by the struggling economy that has been failing to produce graduates that are relevant in driving the recuperation of the Zimbabwean economy. The goal of the new STEM curriculum is to produce economic and industry drivers.

4.3.8 ICT Tools Integration Demands

Three (3) participants admitted using ICT tools in their teaching and learning of STEM related subjects. ICT tools are digital infrastructures such as computers, laptops, data projectors, software programs, printers, scanners and interactive learning box (Lewis, 2003). Three (3) excerpts taken from the participants reveal how they are used and said:

I use tools like the projector and have established a digital library where learners can acquire reading materials such as textbooks and past exam papers in most subject areas (Ndlovu).

I use the projector, that is, visuals to enhance understanding (Moyo).

Mrs Khumalo added:
I use ICT tools to print notes for learners and also download practical experiments for learners.

The findings reveal that a few teachers are employing the use of ICT tools as required by the new STEM curriculum. However, the use of ICT tools by these teachers is still a teacher dominant role as most of the learners are still not being exposed to them in terms of manipulation, as the new STEM curriculum requires. Through exposure and manipulation of ICT tools, learners develop skills through games and communication and also learn about appliances and their different purposes and their appropriate use and care (MoPSE, 2015). The new STEM curriculum is advocating for a hands on approach in the use of ICT tools and also the integration of knowledge and skills. A student that can manipulate objects in different situations is able to think creatively and be innovative which is a necessary skill required in order to revive the comatose Zimbabwean economy.

However most of the participants, five (5), expressed different views and this is three (3) of excerpts:

- There is a need for training in terms of the use of ICT tools, since these are new skills and some of us the older teachers were trained when these tools were not common (Tshuma).

- The ability to use ICT tools is not there and some of the information in the new curriculum is not there in the old textbooks, therefore, research tools use is needed (Ncube).

- It is difficult to use ICT tools as it is a new skill, we need to be trained on how to use projectors and computers in the teaching and learning process (Ndebele).

The findings revealed that some older teachers were unable to integrate ICT tools into their teaching of the new STEM curriculum as they professed the inability to use them. However, in some cases it can be attributed to a fear of new technology and reluctance to try out new ideas (Osborne J. &., 2003). ICT tools have the potential to integrate STEM learning areas along the curriculum and deliver the opportunity for efficient student-teacher communication. (Dawes, 2001). They [ICT tools] offer a platform for learners to integrate concepts with other learners and the teacher and in the process achieve STEM integration. They are vital tools in the endeavour in fully implementing the new STEM curriculum. The integration of ICT tools in
STEM teaching will help in producing the desired learner at a faster pace as they enhance communication and offer the immediacy of sharing and integrating STEM related subjects and concepts.

It can be concluded from the findings that the ICT tools integration into STEM teaching has not been achieved as a majority of STEM related teachers are still showing a phobia to the use of new technologies in teaching and learning. A paradigm shift from traditional methods of teaching needs to happen and the STEM related teacher needs to embrace this technology as it will assist the teacher in boosting his/her pedagogical content knowledge at the same time interlinking the STEM related subjects. New technology tools offer the best platform for this [STEM integration]. A STEM student that is produced will be able to use these skills to collaborate and communicate with other like-minded individuals in order to improve the economy of the country.

4.4 Chapter Summary

This chapter presented and discussed the results that were gathered from the analysis of data in chapter three. The findings indicate that a majority of STEM related subject teachers do not understand the concept of STEM and STEM to STEM education. Most of the teachers are unable to interpret the new STEM curriculum. A majority of teachers are still using the traditional and separatist methods of teaching. The next chapter reveals the study summary, conclusions and recommendations.
CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 INTRODUCTION

This is a concluding chapter. It ends the study with a summary of the research process, and the conclusions. Recommendations drawn from the findings in relation to the research questions. The chapter is concluded with a concluding remark.

5.1 STUDY SUMMARY

5.0.1 Chapter 1: An Introduction to the Study

The study was introduced in this chapter. The chapter discussed the background of the study, the problem under study that is inclusive of the statement of the problem, research questions and objectives, significance of the study, assumptions of the study, delimitations of the study that incorporates the geographical setting of the study, the conceptual parameters and methodology adopted and limitations of the study.

5.0.2 Chapter 2: Literature Review

The study presented and discussed the literature reviewed related to the teacher’s conception in STEM teaching and learning. The chapter revealed that STEM teaching and learning reform in Zimbabwe was introduced against the background of either failed or abandoned reform informing us the successful implementation of such reform might suspect. The chapter revealed that STEM teaching and learning demands teachers to paradigmatically shift from current taught content and pedagogies employed in Zimbabwe to teaching of new STEM content and adopting STEM content supportive pedagogies. The chapter also discussed the integrated meta-cognition and conceptual change model that provides us with the parameters of understanding how teachers comprehend the STEM teaching and learning in this study.
5.0.3 Chapter 3: Research Methodology

The research was rooted within the qualitative research paradigm. A case study design was adopted. The study was carried out at Masotsha High School in Bulawayo Province in the Khami district. The participants in the study were the STEM related science teachers who were selected basing on purposive sampling. Only eight teachers participated in this study. Data were generated through semi-structured interviews and document analysis. Semi-structured interviews were administered on a face to face approach. Audio recording accompanied by field notes were used to capture data in this study. The qualitative content analysis was used in coding and theming the data that was analysed in the study. The study also highlighted issues of validity and the data capturing instruments went through peer and supervisor reviews.

5.0.4 Chapter 4: Presentation and Discussion of Findings

Research findings were reported and discussed in this chapter from the analysis of data in chapter three. Findings revealed that science teachers lacked an understanding of STEM, were unable to relate STEM to STEM education and their interpretation of the new STEM curriculum was still rooted in the traditional and teacher dominant role of the old curriculum. The study also revealed that the majority of teachers are using the traditional and separatist methods of teaching.

This chapter five is concluded with a summary of the study, conclusion, recommendations and final remarks.

5.2 CONCLUSIONS

The study represents an effort to establish the science teachers’ conceptions of STEM teaching and learning and their interpretation of the new STEM curriculum in an effort to curb the economic decline Zimbabwe is facing. Findings proved that science teachers have a surface understanding of STEM as an acronym and as a STEM related subject. Of concern is the inability [of science teachers] to appreciate the integrated nature of STEM education and its application in real-world situations. Integration of STEM education into the new curriculum is poor as the science teachers are still mired in the traditionalist and separatist approach of teaching STEM related subjects and the inability of the ‘new old curriculum’ to have clearly defined content and pedagogy. The participants in this study suggested the need for orientation
in the new curriculum so that they can fully implement it. They were aware in terms of their inability in integrating ICT tools that can form the platform for STEM integrated teaching and learning. Furthermore, the importance of incorporating IKS into the new STEM curriculum was noted, however, a strong pedagogical content is needed to properly implement it.

5.3 **CONCLUSION STATEMENT**

The study findings have implications for curriculum developers, community and the industrial world who should work harmoniously to create a single goal which is a STEM curriculum that is real to the recuperation of the Zimbabwean economy.

5.4 **RECOMMENDATIONS**

From the conclusions that have arisen from the findings, the researcher recommends the following in a bid to improve STEM education:

1. The Ministry of Primary and Secondary Education (MoPSE) should offer workshops on aligning its STEM concept with that of the STEM related teachers.
2. The Ministry of Primary and Secondary Education (MoPSE) must include a course on STEM and STEM education in teacher training curricular at Teachers Colleges and re-orient all the practising STEM related teachers through in-service courses.
3. Science teachers must be capacitated in the expected content, pedagogy and resources needed for the success of the new STEM curriculum through the advancement of their professional and academic qualifications and capacitiation of laboratories.
4. The Curriculum developers should review the ‘new old STEM curriculum’ and include STEM related teachers in every stage of its crafting and the concept of STEM integrated teaching and learning.

5.5 **FINAL REMARKS**

The need for bridging the gap between STEM education and the science teachers, should direct curriculum planners to include the science teachers in every stage of the curriculum planning, development and implementation stages. As per research findings the existing new STEM curriculum should be reviewed either by means of adding the science teachers in every stage of its implementation. The need for capacitating the teachers in terms of resources, content and pedagogy cannot be over emphasised. While the current study focused on the science teachers’
conceptions of STEM teaching and learning, there is need for finding ways in which STEM education can be embedded into the psyche of the current science teacher. This is so because industrial and economic recuperation of Zimbabwe depends on their conceptions of STEM teaching and learning.
REFERENCES


APPENDICES

Appendix 1: Voluntary Consent Form

I ______________________________ agree to participate in the research study titled: science teachers’ conceptions of STEM teaching and learning in Masotsha High School in the Khami District in Bulawayo Province.

I further agree to audio recording during the study. (Mark either “Yes” or “No”)

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I agree to having my **audio recorded**

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I agree to having my **participation in study**

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____________________________________
Name of Research Participant

____________________________________
Designation

____________________________________
Signature

____________________________________
Date

____________________________________
Researcher Name

____________________________________
Signature
Appendix 2: Request for Participation Sample Letter

House Number 1977, Magwegwe New, Bulawayo

20 August 2017

The Secretary
Ministry of Primary and Secondary Education
Bulawayo Metropolitan Province
P O Box 555
Bulawayo
Zimbabwe

Dear Sir/Madam

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT MASOTSHA HIGH SCHOOL IN THE KHAMI DISTRICT IN BULAWAYO PROVINCE

This letter serves to ask for permission to carry out an educational research project at Masotsha High School in the Khami District in Bulawayo Province. The title of the research project is: Science Teachers’ Conceptions of STEM teaching and learning at Masotsha High School in the Khami District in Bulawayo Province.

Purpose: The purpose of the study is to establish science teachers’ comprehension and understanding to STEM teaching and learning.

Procedure: I wish to conduct this study with science teachers at Masotsha High School. Their participation is entirely voluntary. They will be asked to take part in oral audio recorded interviews by responding to semi-structured questions and teacher generated documents will be analysed. Data that is subsequently generated will form the basis of my conclusions and recommendations.

Risks, Discomforts or injury: There are no potential risks related to participating in this study. Although this may be the case, in the event of any direct injury resulting in participating in this study, I can be contacted on +263 783100 544.

Benefits, compensation and additional costs: The participants will not receive any financial or material benefits or any other compensation for taking part in this study. The research is being carried out in partial fulfilment of the requirements of the Master’s Degree in Science
Education in Chemistry at Bindura University of Science Education. Any financial costs related to participation in the study will be met by the researcher. Although there are no financial rewards, participants may gain useful insights into issues associated with STEM teaching and learning that may improve the way they conduct their science lessons.

**Confidentiality:** All data and information generated by this study will be kept confidential. Names of participants will be assigned pseudonyms. The researcher will keep the data material in a secure place which will be destroyed by burning and deletion when the research has been completed.

**Voluntary participation:** Participation in this study is entirely voluntary, and anyone may choose not to take part. Participants who initially agree to take part may choose to withdraw at any time without any consequences. If the researcher decides to use any image of one or more participants, these will be blurred so that they cannot be visually recognised.

**Additional Information:** For any further information regarding their rights as research participants, anyone is free to contact Dr V. Mpofu at tvmpofu@gmail.com or on her mobile, +263 775 184 200.

**Conclusion:** I am happy to answer any questions on any aspect of this study that may be unclear to you. I can be contacted using the e-mail address of mobile number stated at the bottom of this letter.

**Authorisation:** You may authorise that the research be conducted by signing on this letter or by giving a separate written approval.

Yours sincerely

Shaibu Adini Phiri Reg. Number: B1544974, Mobile: +263 783100 544, Email: shaibuphiri.m@gmail.com
Appendix 3: SSI Guide

Section A: Participant background

<table>
<thead>
<tr>
<th>Participant</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SSI session number</td>
<td></td>
</tr>
<tr>
<td>Date and Time</td>
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</tbody>
</table>

Section B: SSI items

The items here were developed to solicit the participants’ meaning of STEM, STEM Education and STEM and their Interpretation of the STEM curriculum document

1) What is your understanding of:
   a. STEM
   b. STEM teaching and learning?

2) How is STEM related to STEM teaching and learning?

3) What are the similarities and differences between the old and new curriculum?

4) What new demands is the curriculum placing on you?

5) How are you adapting to the new curriculum demands?

6) What content are you currently teaching in your subject?

7) How are you teaching this content?

8) What activities do you engage in after your lesson delivery?

Section C: General Comments

Section D: Closing Remarks

Thank you very much for your precious time. I hope the research will be a success due to your unwavering support.
Appendix 4a: New Curriculum Document Analysis Guide

Section A: Document info

<table>
<thead>
<tr>
<th>Teacher</th>
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</thead>
<tbody>
<tr>
<td>Name of document</td>
<td></td>
</tr>
<tr>
<td>Subject:</td>
<td></td>
</tr>
<tr>
<td>Date and Time</td>
<td></td>
</tr>
</tbody>
</table>

Section B: DA items

1) What are the definitions of?

a. STEM  b. STEM teaching and learning in the new curriculum?

2) How does the new curriculum relate STEM to STEM teaching and learning?

3) What are the similarities and differences between the old and new curriculum?

4) What demands the new curriculum placing on teachers?

5) How does new curriculum direct teachers to do?

6) What content is covered by the new curriculum?

7) How must this content be taught?

8) What activities are covered by the new curriculum after lesson delivery?

Section C General Comments
Appendix 4b: Teacher Generated Document Analysis Guide

Section A: Document info

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Name of document</td>
<td></td>
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<tr>
<td>Subject:</td>
<td></td>
</tr>
<tr>
<td>Date and Time</td>
<td></td>
</tr>
</tbody>
</table>

Section B: DA items

1) What definitions of:
   a. STEM  
b. STEM teaching and learning are be drawn from teacher generated documents?

2) How does the teacher generated documents relate STEM to STEM teaching and learning?

3) What similarities and differences between STEM to STEM teaching and learning can be drawn from teachers’ generated documents?

4) What evidence of the teachers’ understanding of the demands of the new curriculum is in the teacher generated documents?

5) How are teachers adapting to the new curriculum demands from their professional documents?

6) What content is covered in the teacher generated documents?

7) How is this content planned to be taught?

8) What after lesson delivery activities are covered in the teacher generated documents?

Section C General Comments
DEPARTMENT OF EDUCATION

BINDURA UNIVERSITY OF SCIENCE EDUCATION

Date: 24 August 2017

TO WHOM IT MAY CONCERN

RE: NAME: Phiri Shaibu Adini

PROGRAMME: MScEdChemistry

REGISTRATION NUMBER: B1544974

PART: 2.2

This memo serves to confirm that the above is a bona fide student at Bindura University of Science Education in the Faculty of Science Education.

The student has to undertake research and thereafter present Research Thesis in partial fulfillment of the Masters of Science Education Degree programme. The research topic is:

Science teachers’ conceptions in STEM teaching and learning in the Khumri District Schools in Bulawayo Metropolitan Province.

In this regard, the department kindly requests your permission to allow the student to carry out his research in your institutions.

Your co-operation and assistance is greatly appreciated.

Thank you

[Signature]

Dr E. Mandoga

PROGRAMME COORDINATOR
Appendix 6: Bulawayo Province and Khami District Authority

11 September 2017

Phiri Shaibu Adini
Bindura University of Science Education

RESEARCH ON: SCIENCE TEACHERS' CONCEPTION IN STEM TEACHING AND LEARNING AT 'O' LEVEL IN KHAMI DISTRICT SCHOOLS IN BULAWAYO METROPOLITAN PROVINCE

With reference to your application dated 24 August 2017 to carry out a research on the above mentioned topic in the Education Institutions under the jurisdiction of the Bulawayo Province permission is hereby granted. However, you should liaise with the Heads of the Institutions/Schools for clearance before carrying out your research.

It will also be appreciated if you could supply the Bulawayo Province with a final copy of your research which may contain information useful to the development of education in the province.
Appendix 7: School Authority Letter

MASOTSHA HIGH SCHOOL
P.O BOX 8
MAGWEGWE
BULAWAYO

TEL: 09-521330

3 April 2018

Bindura University of Science Education
PO Box 1020
Bindura

RE: PERMISSION TO CONDUCT A RESEARCH FOR SHAIBU ADINI PHIRI B1544974 AT THE
ABOVE NAMED SCHOOL

I Gumede N. being Head of Masotsha High School do hereby authorize Shaibu Adini Phiri to
carry out his research study entitled: Science Teachers’ Conceptions in STEM Teaching and
learning at O level at Masotsha High School in the Khami District in Bulawayo Province.

Yours Faithfully

N. Gumede